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# International Energy Outlook 2016

*Independent Statistics & Analysis*

U.S. Energy Information Administration

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## Electronic access and related reports

IEO2016, including text, forecast tables, and graphics, will be available on the EIA Home Page (www.eia.gov/ieo) by June 30, 2016, including text, forecast tables, and graphics. To download the entire publication in Portable Document Format (PDF), go to www.eia.gov/forecasts/ieo/pdf/0484(2016).pdf.

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# International Energy Outlook 2016

## With Projections to 2040

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# Preface

The *International Energy Outlook 2016* (IEO2016) presents an assessment by the U.S. Energy Information Administration (EIA) of the outlook for international energy markets through 2040. U.S. projections appearing in IEO2016 are consistent with those published in EIA's *Annual Energy Outlook 2015* (AEO2015). IEO2016 is provided as a service to energy managers and analysts, both in government and in the private sector. The projections are used by international agencies, federal and state governments, trade associations, and other planners and decisionmakers. They are published pursuant to the Department of Energy Organization Act of 1977 (Public Law 95-91), Section 205(c).

The IEO2016 energy consumption projections are divided according to Organization for Economic Cooperation and Development members (OECD)[1] and nonmembers (non-OECD). OECD members are divided into three basic country groupings: OECD Americas (United States, Canada, and Mexico/Chile), OECD Europe, and OECD Asia (Japan, South Korea, and Australia/New Zealand). Non-OECD countries are divided into five separate regional subgroups: non-OECD Europe and Eurasia (which includes Russia); non-OECD Asia (which includes China and India); Middle East; Africa; and non-OECD Americas (which includes Brazil). In some instances, the IEO2016 energy production models have different regional aggregations to reflect important production sources (for example, Middle East OPEC is a key region in the projections for liquids production). Complete regional definitions are listed in Appendix M.

IEO2016 focuses exclusively on marketed energy. Nonmarketed energy sources,[2] which continue to play an important role in some developing countries, are not included in the estimates. The IEO2016 projections are based on existing U.S. and foreign government laws and regulations. In general, IEO2016 reflects the effects of current policies—often stated through regulations—within the projections. EIA analysts attempt to interpret the likely effects of announced country targets when the implementation of those targets will require new policies that have not been formulated or announced.

The report begins with a review of world trends in energy demand and the major macroeconomic assumptions used in deriving the IEO2016 projections, along with the major sources of uncertainty in the projections, which extend through 2040. In addition to the Reference case projections, High Economic Growth and Low Economic Growth cases were developed to consider the effects of higher and lower growth paths for economic activity than are assumed in the Reference case. IEO2016 also includes a High Oil Price case and, alternatively, a Low Oil Price case. The resulting projections—and the uncertainty associated with international energy projections in general—are discussed in Chapter 1, "World energy demand and economic outlook."

Projections for energy consumption and production by fuel—petroleum and other liquid fuels, natural gas, and coal—are presented in Chapters 2, 3, and 4, along with reviews of the current status of each fuel on a worldwide basis. Chapter 5 discusses the projections for world electricity markets—including nuclear power, hydropower, and other marketed renewable energy resources—and presents projections of world installed generating capacity. Chapter 6 presents a discussion of energy used in the buildings sector (residential and commercial). Chapter 7 provides a discussion of industrial sector energy use. Chapter 8 includes a detailed look at the world's transportation energy use. Finally, Chapter 9 discusses the outlook for global energy-related carbon dioxide emissions.

## Objectives of the IEO2016 projections

The projections in IEO2016 are not statements of what will happen, but what might happen given the specific assumptions and methodologies used for any particular scenario. The Reference case projection is a business-as-usual trend estimate, given known technology and technological and demographic trends. EIA explores the effects of alternative assumptions in other scenarios with different macroeconomic growth rates and world oil prices. The IEO2016 cases generally assume that current laws and regulations are maintained throughout the projections. Thus, the projections provide policy-neutral baselines that can be used to analyze international energy markets.

While energy markets are complex, energy models are simplified representations of energy production and consumption, regulations, and producer and consumer behavior. Projections are highly dependent on the data, methodologies, model structures, and assumptions used in their development. Behavioral characteristics are indicative of real-world tendencies, rather than representations of specific outcomes.

Energy market projections are subject to much uncertainty. Many of the events that shape energy markets are random and cannot be anticipated. In addition, future developments in technologies, demographics, and resources cannot be foreseen with certainty. Key uncertainties in the IEO2016 projections are addressed through alternative cases.

EIA has endeavored to make these projections as objective, reliable, and useful as possible. They are intended to serve as an adjunct to, not a substitute for, a complete and focused analysis of public policy initiatives.

[1]OECD includes all members of the organization as of January 1, 2016, in all the time series included in this report. Israel, which became a member in 2010, is included in OECD Europe for statistical reporting purposes.

[2]Nonmarketed energy sources include selected energy consumption data for which the energy is not bought or sold, either directly or indirectly, as an input to marketed energy—particularly, traditional fuels such as fuelwood, charcoal, agricultural waste, and animal dung used for cooking and water heating. EIA does not estimate or project total consumption of nonmarketed energy.

Appendix A contains summary tables for the IEO2016 Reference case projections of world energy consumption, GDP, energy consumption by fuel, carbon dioxide emissions, and regional population growth. Summary tables of projections for the High and Low Economic Growth cases are provided in Appendixes B and C, respectively; and projections for the High and Low Oil Price cases are provided in Appendixes D and E, respectively. Reference case projections for delivered energy consumption by end-use sector and region are presented in Appendix F. Appendix G contains summary tables of projections for world petroleum and other liquids production in the three IEO2016 oil price cases. Appendix H contains summary tables of Reference case projections for installed electric power capacity by fuel and regional electricity generation. Appendix I contains summary tables for projections of world natural gas production in the Reference case. Appendix J includes tables of population, per capita economic output, energy intensity of the economy, and carbon intensity of energy. In Appendix K, a set of comparisons of projections from the International Energy Agency's World Energy Outlook 2015 with the IEO2016 projections is presented. Comparisons of the IEO2016 and IEO2013 projections are also presented in Appendix K. Appendix L describes the models used to generate the IEO2016 projections. Appendix M defines the regional designations included in the report.

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# Executive Summary

The outlook for energy use worldwide presented in the *International Energy Outlook 2016* (IEO2016) continues to show rising levels of demand over the next three decades, led by strong increases in countries outside of the Organization for Economic Cooperation and Development (OECD),[3] particularly in Asia. Non-OECD Asia, including China and India, account for more than half of the world's total increase in energy consumption over the 2012 to 2040 projection period. By 2040, energy use in non-OECD Asia exceeds that of the entire OECD by 40 quadrillion British thermal units (Btu) in the IEO2016 Reference case (Figure ES-1).

In the IEO2016 Reference case, total world energy consumption rises from 549 quadrillion Btu in 2012 to 815 quadrillion Btu in 2040, an increase of 48%. Most of the world's energy growth will occur in the non-OECD nations, where relatively strong, long-term economic growth drives increasing demand for energy. Non-OECD energy consumption increases by 71% between 2012 and 2040 compared with an increase of 18% in OECD nations. Energy use in the combined non-OECD region first exceeded that of the OECD in 2007 and by 2012, non-OECD countries accounted for 57% of total world energy consumption. By 2040, almost two-thirds of the world's primary energy will be consumed in the non-OECD economies.

Economic growth—as measured in gross domestic product (GDP)—is a key determinant in the growth of energy demand. The world's GDP (expressed in purchasing power parity terms) rises by 3.3%/year from 2012 to 2040. The fastest rates of growth are projected for the emerging, non-OECD countries, where combined GDP increases by 4.2%/year. In OECD countries, GDP grows at a much slower rate of 2.0%/year over the projection as a result of their more mature economies and slow or declining population growth trends. The strong projected economic growth rates in the non-OECD drive the fast-paced growth in future energy consumption among those nations.

## World energy markets by fuel type

The IEO2016 Reference case projects increased world consumption of marketed energy from all fuel sources through 2040 (Figure ES-2). Renewables are the world's fastest-growing energy source over the projection period. Renewable energy consumption increases by an average 2.6%/year between 2012 and 2040. Nuclear power is the world's second fastest-growing energy source, with consumption increasing by 2.3%/year over that period.

Even though consumption of nonfossil fuels is expected to grow faster than consumption of fossil fuels, fossil fuels still account for 78% of energy use in 2040. Natural gas is the fastest-growing fossil fuel in the outlook. Global natural gas consumption increases by 1.9%/year. Abundant natural gas resources and robust production—including rising supplies of tight gas, shale gas, and coalbed methane—contribute to the strong competitive position of natural gas. Although liquid fuels—mostly petroleum-based—remain the largest source of world energy consumption, the liquids share of world marketed energy consumption falls from 33% in 2012 to 30% in 2040. Contributing to the decline are rising oil prices in the long term, which lead many energy users to adopt more energy-efficient technologies and to switch away from liquid fuels when feasible. Coal, the world's slowest-growing energy source, rises by 0.6%/year and is surpassed by natural gas by 2030.

**Figure ES-1. World energy consumption by country grouping, 2012–40 (quadrillion Btu)**

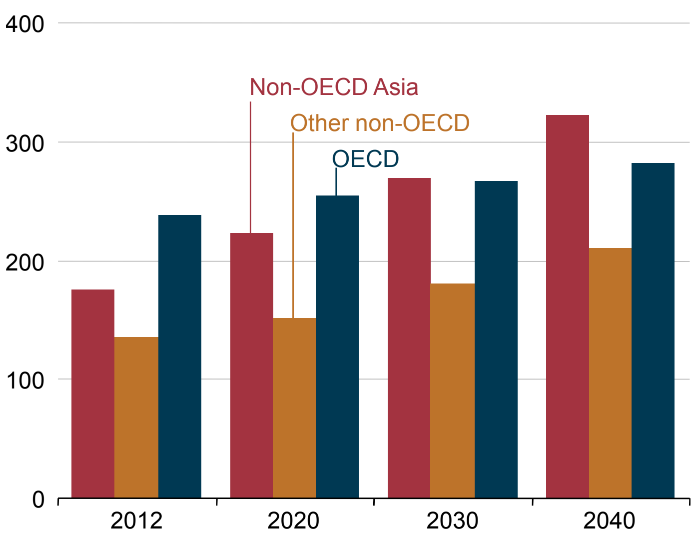
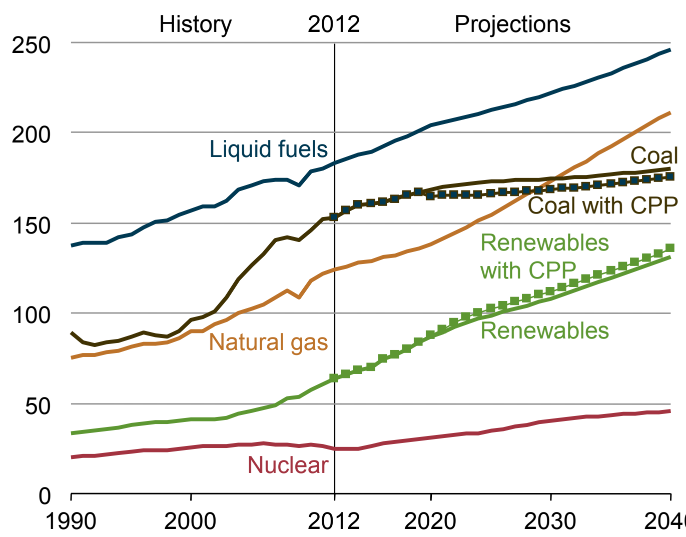



**Figure ES-2. Total world energy consumption by energy source, 1990–2040 (quadrillion Btu)**




Note: Dotted lines for coal and renewables show projected effects of the U.S. Clean Power Plan.

[3]For consistency, OECD includes all members of the organization as of January 1, 2016, throughout all the time series included in this report. OECD member countries as of January 1, 2016, were Austria, Australia, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. For statistical reporting purposes, Israel is included in OECD Europe. See Appendix M for the complete list of regional definitions used in the IEO2016

The IEO2016 Reference case projections do not include the potential effects of the recently finalized Clean Power Plan (CPP) regulations in the United States. The U.S. Energy Information Administration's (EIA) preliminary analysis of the proposed CPP[4] showed potential reductions of 21% (about 4 quadrillion Btu) in U.S. coal consumption in 2020 and 24% (almost 5 quadrillion Btu) in 2040 relative to the IEO2016 Reference case projection. With the CPP, U.S. renewable energy use in 2020 would be 7% (about 1 quadrillion Btu) higher than in the IEO2016 Reference case, and in 2040 it would be 37% (4 quadrillion Btu) higher than in the IEO2016 Reference case. U.S. consumption of petroleum and other liquids and of natural gas would be slightly lower with the CPP than in the IEO2016 Reference case. Key tables and figures throughout the report provide results that include the CPP where they differ significantly from the Reference case.

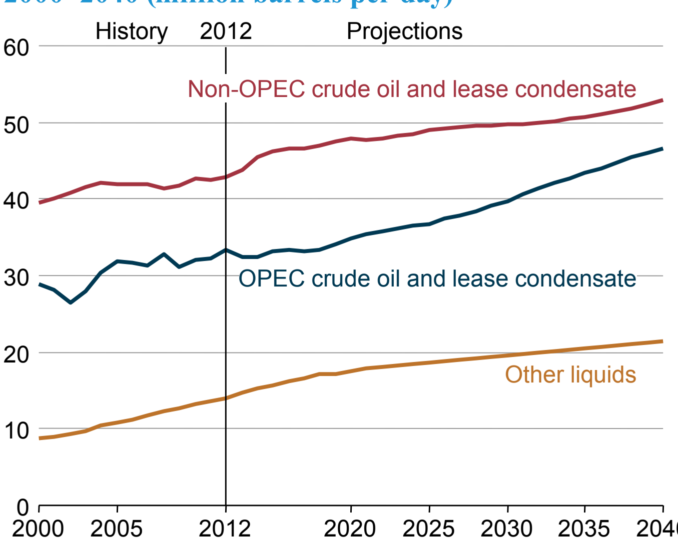
## *Liquid fuels*

World use of petroleum and other liquid fuels grows from 90 million barrels per day (b/d) in 2012 to 100 million b/d in 2020 and to 121 million b/d in 2040. Most of the growth in liquid fuels consumption is in the transportation and industrial sectors. In the transportation sector, in particular, liquid fuels continue to provide most of the energy consumed. Although advances in nonliquids-based transportation technologies are anticipated, they are not enough to offset the rising demand for transportation services worldwide. Liquid fuels consumed for transportation increases by an average of 1.1%/year from 2012 to 2040, and the transportation sector accounts for 62% of the total increase in delivered liquid fuels use. Most of the remaining increase in liquid fuels consumption is attributed to the industrial sector, where the chemicals industry continues to consume large quantities of petroleum feedstocks throughout the projection period. The use of liquids declines for electric power generation.

To satisfy the increase in world liquids demand in the IEO2016 Reference case, liquids production increases by 30.5 million b/d from 2012 to 2040, including the production of crude oil and lease condensate[5] and other liquid fuels.[6] The IEO2016 Reference case assumes that countries in the Organization of the Petroleum Exporting Countries (OPEC) will invest in incremental production capacity to maintain a 39%–43% share of total world liquids production through 2040, consistent with their share over the past 15 years. Increasing volumes of crude oil and lease condensate from OPEC producers contribute 13.2 million b/d to the total increase in world liquids production, and crude oil and lease condensate supplies from non-OPEC countries add another 10.2 million b/d (Figure ES-3).

Other liquids resources from both OPEC and non-OPEC sources grow on average by 1.5%/year over the projection period and currently supply a relatively small portion of total world petroleum and other liquid fuels. In 2012, other liquids accounted for about 16% of total liquid fuels production, and that share is projected to increase modestly to 18% in 2040. Natural gas plant liquids (NGPL) is the largest component of other liquids, accounting for 67% of the other liquid fuels in 2012. The increase in NGPL production in the IEO2016 is directly related to the increase in natural gas production, because NGPL is often a coproduct. In contrast, excluding NGPL, increased production of the remaining other liquids (primarily biofuels, CTL, and GTL) occurs in response to high prices that support expansion of their production with available domestic resources, such as crops, coal, or natural gas. In the IEO2016 Reference case, sustained low oil prices in the early years of the projection make the development of the non-NGPL other liquids less economically attractive. In addition to being price-sensitive, biofuels development, in particular, often depends heavily on policies or mandates to support growth.

**Figure ES-3. Petroleum and other liquid fuels production by region and type in the Reference case, 2000–2040 (million barrels per day)**




## *Natural gas*

Worldwide natural gas consumption is projected to increase from 120 trillion cubic feet (Tcf) in 2012 to 203 Tcf in 2040 in the IEO2016 Reference case. By energy source, natural gas accounts for the largest increase in world primary energy consumption. Abundant natural gas resources and robust production contribute to the strong competitive position of natural gas among other resources. Natural gas remains a key fuel in the electric power sector and in the industrial sector. In the power sector, natural gas is an attractive choice for new generating plants given its moderate capital cost and attractive pricing in many regions as well as the relatively high fuel efficiency and moderate capital cost of gas-fired plants. Additionally, as more governments begin implementing national or regional plans to reduce carbon dioxide (CO2) emissions, natural gas may displace consumption of the more carbon-intensive coal and liquid fuels.

To meet the rising natural gas demand projected in the IEO2016 Reference case, the world's natural gas producers increase

[4]U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

[5]Crude and lease condensate includes tight oil, shale oil extra-heavy crude oil, field condensate, and bitumen.

[6]Other liquid fuels include natural gas plant liquids (NGPL), biofuels, gas-to-liquids (GTL), coal-to-liquids (CTL), kerogen, and refinery gain.

supplies by nearly 69% from 2012 to 2040. The largest increases in natural gas production from 2012 to 2040 occur in non-OECD Asia (18.7 Tcf), the Middle East (16.6 Tcf), and the OECD Americas (15.5 Tcf) (Figure ES-4). In China, production increases by 15.0 Tcf as the country expands development of its shale resources. The United States and Russia increase natural gas production by 11.3 Tcf and 10.0 Tcf, respectively. In Russia, production growth is supported primarily by increasing development of resources in the country's Arctic and eastern regions. U.S. production growth comes mainly from shale resources. China, the United States, and Russia account for nearly 44% of the overall increase in world production of natural gas between 2012 and 2040.

World natural gas trade, both by pipeline and by shipment in the form of liquefied natural gas (LNG), is poised to increase in the future. World LNG trade more than doubles, from 12 Tcf in 2012 to 29 Tcf in 2040. Most of the increase in liquefaction capacity occurs in Australia and North America, where a number of new liquefaction projects are planned or under construction, many of which are expected to become operational within the next decade. Despite the strong growth in LNG trade, flows of natural gas by pipeline still account for most of the global natural gas trade in the IEO2016 Reference case, which includes several new long-distance pipelines and expansions of existing infrastructure through 2040. The largest volumes of natural gas traded internationally by pipeline currently are in the Americas (between Canada and the United States) and in Europe (among many OECD and non-OECD countries).

### *Coal*

Coal is the world's slowest-growing energy source in the IEO2016 Reference case, rising by an average 0.6%/year, from 153 quadrillion Btu in 2012 to 180 quadrillion Btu in 2040. Throughout the projection, the top three coal-consuming countries are China, the United States, and India, which together account for more than 70% of world coal use. China currently accounts for almost half of the world's total coal consumption, but a slowing economy and plans to implement policies to address air pollution and climate change contribute to declining coal use in China in the later years of the projection (Figure ES-5).

Coal consumption projections in the IEO2016 Reference case do not include the impact of the finalized Clean Power Plan regulations in the United States. Including the CPP would reduce world coal consumption to 165 quadrillion Btu in 2020 and to 176 quadrillion Btu in 2040, based on EIA's analysis of the CPP proposed rule.[7] EIA's analysis of the final rule, which is being prepared for release in EIA's Annual Energy Outlook 2016, is expected to show a roughly similar impact on projections of U.S. coal use.

Global coal production is projected to increase from 9 billion short tons in 2012 to 10 billion short tons in 2040. Most of the projected growth in world coal production occurs in India, China, and Australia. Their combined share of total world coal production increases in the IEO2016 Reference case from 60% in 2012 to 64% in 2040, but the share of the world's leading coal producer, China, decreases from 48% in 2012 to 44% in 2040. There is significant regional variation in the prospects for coal production in the IEO2016 Reference case, with large increases projected for India; sizeable increases in production in Africa and Russia; growth that slows and then gradually declines after 2025 in China; and little change in OECD Europe or the United States. However, with the CPP in place, U.S. coal production declines significantly between 2012 and 2040.

**Figure ES-4. World increase in natural gas production, 2012–40 (trillion cubic feet)**

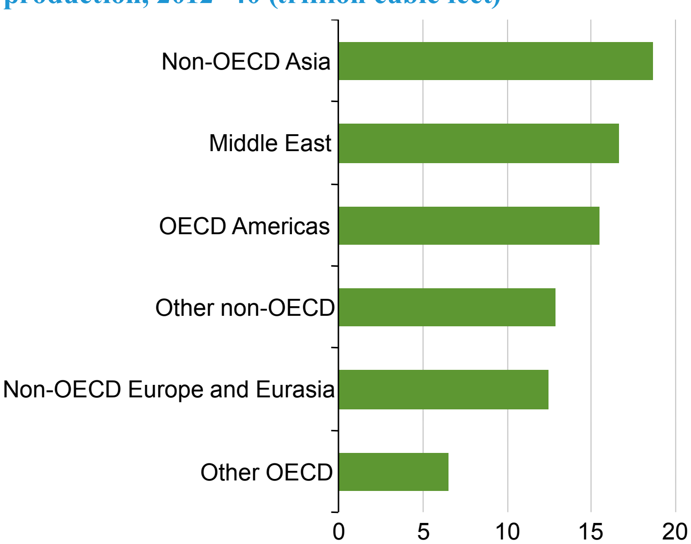
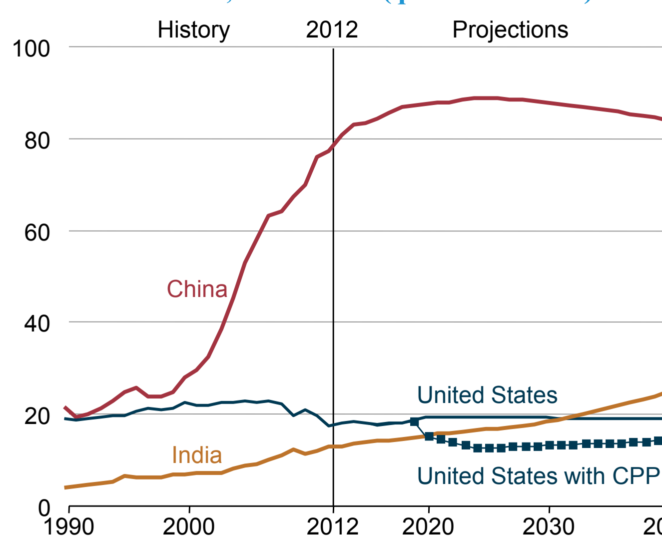



**Figure ES-5. Coal consumption in China, India, and the United States, 1990–2040 (quadrillion Btu)**




Note: Dotted line for U.S. coal consumption shows projected effect of the U.S. Clean Power Plan.

[7]U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

### Electricity

World net electricity generation increases by 69% in the IEO2016 Reference case, from 21.6 trillion kilowatthours (kWh) in 2012 to 25.8 trillion kWh in 2020 and to 36.5 trillion kWh in 2040. The electric power sector remains among the most dynamic areas of growth among all energy markets. 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, noncompetitive grids to integrated national and even international markets.

The strongest growth in electricity generation is projected to occur among the developing, non-OECD nations. Increases in non-OECD electricity generation average 2.5%/year from 2012 to 2040, as rising living standards increase demand for home appliances and electronic devices, as well as for commercial services, including hospitals, schools, office buildings, and shopping malls. In the OECD nations, where infrastructures are more mature and population growth is relatively slow or declining, electric power generation increases by an average of 1.2%/year from 2012 to 2040 in the IEO2016 Reference case.

Long-term global prospects continue to improve for generation from renewable energy sources, natural gas, and nuclear power (Figure ES-6). Renewables are the fastest-growing source of energy for electricity generation, with average increases of 2.9%/year from 2012 to 2040. 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 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.

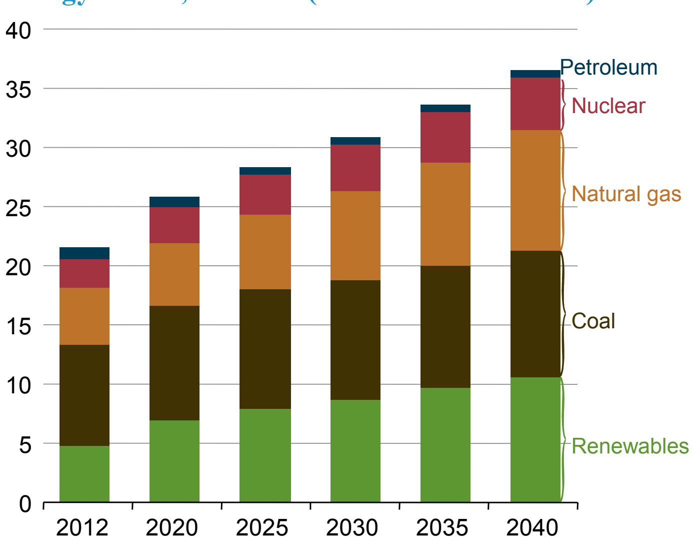
Many countries, particularly among the OECD, have enacted environmental policies and regulations intended to reduce greenhouse gas emissions from electric power plants by decreasing the use of fossil fuels. As a result, the role of coal as the dominant fuel for electric power plants is declining. In contrast to renewables, which grow by an average of 2.9%/year from 2012 to 2040, coal-fired net generation increases by 0.8%/year. At the end of the projection period, generation from renewable energy sources equals generation from coal on a worldwide basis. 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 significantly.

Electricity generation from nuclear power worldwide increases from 2.3 trillion kWh in 2012 to 3.1 trillion kWh in 2020 and to 4.5 trillion kWh in 2040 in the IEO2016 Reference case, as concerns about energy security and greenhouse gas emissions support the development of new nuclear generating capacity. Virtually all the projected net expansion in the world's installed nuclear power capacity occurs in the non-OECD region, led by China's addition of 139 gigawatts (GW) of nuclear capacity from 2012 to 2040. Among the OECD countries, only South Korea has a sizable increase in nuclear capacity (15 GW). Capacity reductions in Canada and OECD Europe, and in Japan (where nuclear capacity in 2040 in the IEO2016 Reference case remains below the level before the March 2011 Fukushima Daiichi nuclear disaster), more than offset the increase in South Korea's nuclear capacity. As a result, the combined capacity of all OECD nuclear power plants drops by 6 GW from 2012 to 2040.

## World delivered energy use by sector

It is important to examine patterns in the consumption of energy delivered to end users to fully assess future global energy use. This section discusses delivered energy consumption in the buildings, industrial, and transportation sectors. Energy losses associated with electricity generation and transmission are not included in the consumption numbers.

**Figure ES-6. World net electricity generation by energy source, 2012–40 (trillion kilowatthours)**




### Residential and commercial buildings

The buildings sector, which consists of residential and commercial end users, accounts for 20% of the total delivered energy consumed worldwide. In the residential sector—where energy use is defined as the energy consumed by households, excluding transportation uses—world delivered energy consumption grows by an average of 1.4%/year from 2012 to 2040. In the non-OECD, residential energy use increases by an average of 2.1%/year from 2012 to 2040, a result of strong economic growth and rising standards of living. In the OECD economies, residential sector energy use grows much more slowly, averaging 0.6%/year over the projection. The lower OECD growth rate results from relatively slow GDP and population growth, as well as improvements in building shells and the efficiency of appliances and equipment.

Similarly, in the commercial sector, which consists of profit-seeking and nonprofit enterprises engaged in commercial-scale activity (often called the service sector), the highest rates of growth in energy consumption also occur in non-OECD nations in the IEO2016 Reference case. Globally, EIA projects average growth in commercial energy use of 1.6%/year from 2012 to 2040. Non-OECD commercial sector delivered energy use increases by 2.4%/year in the IEO2016 Reference case, and OECD commercial energy use expands by 1.1%/year. Slow expansion of GDP and low or declining population growth in many OECD nations contribute to slower anticipated rates of growth in commercial energy demand. In addition, continued efficiency improvements moderate the growth of energy demand over time, as relatively inefficient equipment is replaced with newer, more efficient stock.

### *Industrial*

The industrial sector continues to account for the largest share of delivered energy consumption to end users throughout the projection period. In the IEO2016 Reference case, the world's industrial sector accounts for more than half of total delivered energy use through 2040. Although the industrial sector is the largest energy-consuming end-use sector throughout the projection period, it is not the fastest-growing end-use sector, with growth in the residential sector, the commercial sector, and the transportation sector each outpacing industrial sector growth through 2040.

In the IEO2016 Reference case, worldwide industrial sector energy consumption is projected to increase by an average of 1.2%/year. Most of the long-term industrial sector energy growth occurs in non-OECD countries. From 2012 to 2040, industrial energy consumption in non-OECD countries grows by an average of 1.5%/year, compared with 0.5%/year in OECD countries. Despite the expected growth in non-OECD industrial sector energy use, the industrial share of total delivered energy in the non-OECD countries declines during the projection period, from 64% in 2012 to 59% in 2040, as a result of the move away from energy-intensive manufacturing in many emerging, non-OECD economies and as a result of more rapid growth of energy consumption in all other end-use sectors.

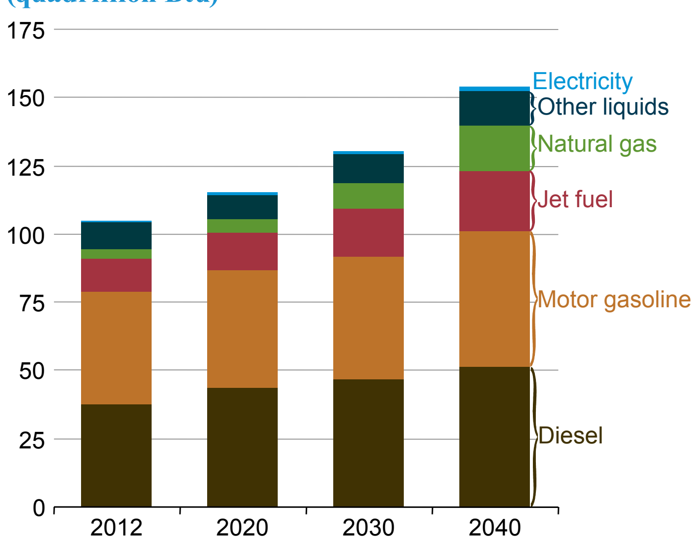
### *Transportation*

Energy use in the transportation sector includes the energy consumed in moving people and goods by road, rail, air, water, and pipeline. In the IEO2016 Reference case, world delivered energy consumption in the transportation sector increases at an annual average rate of 1.4%. Virtually all (94%) of the growth in transportation energy use occurs in the developing, non-OECD economies. Continuing economic growth leads to rising standards of living that result in demand for personal travel and freight transport to meet growing consumer demand for goods in non-OECD nations. In OECD nations, the combination of well-established consuming patterns, comparatively slow economic and population growth rates, and vehicle efficiency improvements, leads to an average increase in total transportation energy use of only 0.2%/year from 2012 to 2040.

Worldwide, liquid fuels remain the dominant source of transportation energy consumption, although their share of total transportation energy declines somewhat over the projection period, from 96% in 2012 to 88% in 2040. World liquid fuels consumption grows by 36 quadrillion Btu in the IEO2016 Reference case projection, with diesel (including biodiesel) showing the largest gain (13 quadrillion Btu), jet fuel consumption increasing by 10 quadrillion Btu, and motor gasoline (including ethanol blends) increasing by 9 quadrillion Btu (Figure ES-7). Motor gasoline remains the largest transportation fuel, but its share of total transportation energy consumption declines from 39% in 2012 to 33% in 2040.

The share of natural gas as a transportation fuel grows from 3% in 2012 to 11% in 2040. As a result of favorable fuel economics, a strong increase is projected for the natural gas share of total energy use by large trucks in the IEO2016 Reference case, from 1% in 2012 to 15% in 2040. In addition, 50% of bus energy consumption is projected to be natural gas in 2040, as well as 17% of freight rail, 7% of light-duty vehicles, and 6% of domestic marine vessels. Electricity remains a minor fuel for the world's transportation energy use, although its importance in passenger rail transportation remains high. The electricity share of total light-duty vehicle energy consumption grows to 1% in 2040, as new plug-in electric vehicles increasingly penetrate the total light-duty stock.

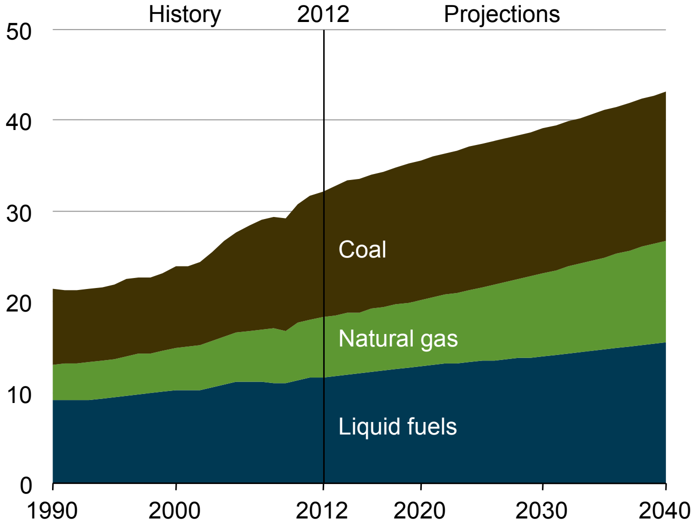
**Figure ES-7. World transportation sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**




## World carbon dioxide emissions

World energy-related CO2 emissions rise from 32.2 billion metric tons in 2012 to 35.6 billion metric tons in 2020 and to 43.2 billion metric tons in 2040 in the IEO2016 Reference case—an increase of 34% over the projection period. Much of the growth in emissions is attributed to developing non-OECD nations, many of which continue to rely heavily on fossil fuels to meet the fast-paced growth of energy demand. In the IEO2016 Reference case, non-OECD emissions in 2040 total 29.4 billion metric tons, or about 51% higher than the 2012 level. In comparison, OECD emissions total 13.8 billion metric tons in 2040, or about 9% higher than the 2012 level. The IEO2016 Reference case estimates do not include effects of the recently finalized Clean Power Plan regulations in the United States, which reduce projected U.S. emissions in 2040 by 0.5 billion metric tons, based on EIA's analysis of the CPP proposed rule.[8]

**Figure ES-8. World energy-related carbon dioxide emissions by fuel type, 1990–2040 (billion metric tons)**




Energy-related CO2 emissions from the use of liquid fuels, natural gas, and coal increase in the IEO2016 Reference case, with the relative contributions of the individual fuels shifting over time (Figure ES-8). In 1990, CO2 emissions associated with the consumption of liquid fuels accounted for the largest portion (43%) of global emissions. In 2012, CO2 emissions associated with the consumption of liquid fuels fell to 36% of total emissions, and they are projected to remain at that level through 2040 in the IEO2016 Reference case. Coal, which is the most carbon-intensive fossil fuel, became the leading source of world energy-related CO2 emissions in 2006, and it remains the leading source through 2040. However, although coal accounted for 39% of total emissions in 1990 and 43% in 2012, its share is projected to stabilize and then decline to 38% in 2040, only slightly higher than the liquids share. The natural gas share of CO2 emissions, which was a relatively small 19% of total energy-related CO2 emissions in 1990 and 20% in 2012, increases over the projection to 26% of total fossil fuel emissions in 2040.

[8]U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

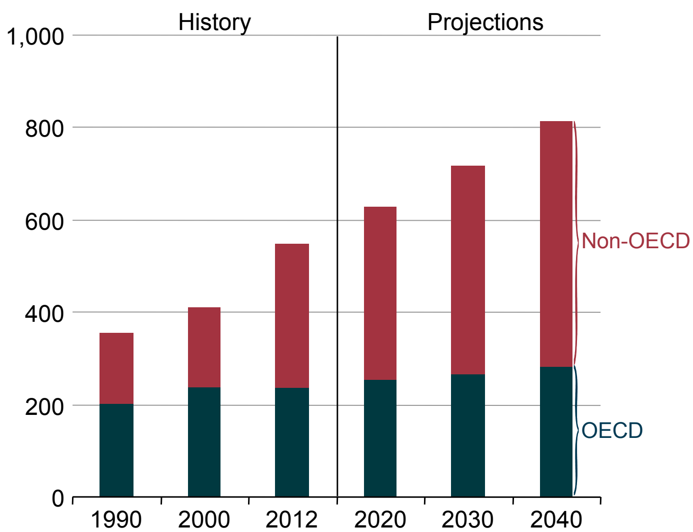
# Chapter 1
# World energy demand and economic outlook

## Overview

The *International Energy Outlook 2016* (IEO2016) Reference case projects significant growth in worldwide energy demand over the 28-year period from 2012 to 2040. Total world consumption of marketed energy expands from 549 quadrillion British thermal units (Btu) in 2012 to 629 quadrillion Btu in 2020 and to 815 quadrillion Btu in 2040—a 48% increase from 2012 to 2040 (Table 1-1 and Figure 1-1). The IEO2016 Reference case assumes known technologies and technological and demographic trends, generally reflects the effects of current policies, and does not anticipate new policies that have not been announced *(see box below)*.

The IEO2016 Reference case projections do not include the effects of the recently finalized Clean Power Plan (CPP) regulations in the United States. The U.S. Energy Information Administration's (EIA) preliminary analysis of the proposed CPP[9] shows potential reductions of 21% (about 4 quadrillion Btu) in U.S. coal consumption in 2020 and 24% (almost 5 quadrillion Btu) in 2040 relative to the IEO2016 Reference case projection. With the CPP, U.S. renewable energy use in 2020 would be 7% (about 1 quadrillion Btu) higher than in the Reference case, and in 2040 it would be 37% (4 quadrillion Btu) higher than in the Reference case. U.S. consumption of petroleum and other liquid fuels and of natural gas would be slightly lower with the CPP than in the Reference case.

### Figure 1-1. World energy consumption, 1990–2040 (quadrillion Btu)




### EIA's handling of non-U.S. policies in the *International Energy Outlook*

The *International Energy Outlook* (IEO), in general, reflects the effects of current policies—often stated through regulations—within the projections. The IEO does not incorporate policies that are not currently in place. Within the context of international modeling, incorporating existing policies and regulations and interpreting announced country targets can be complex. EIA analysts consider policies, regulations, and targets in major countries and regions within the 16 IEO regions with the goal of realistically incorporating them into the projections.

The incorporation of U.S. policies in IEO2016 is consistent with their incorporation in the *Annual Energy Outlook 2015* (AEO2015). The final Clean Power Plan (CPP) rule, which was issued in August 2015, is not included in the AEO2015

*(continued on page 8)*

### Table 1-1. World energy consumption by country grouping, 2012–40 (quadrillion Btu)

| Region | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| **OECD** | **238** | **254** | **261** | **267** | **274** | **282** | **0.6** |
| Americas | 118 | 126 | 128 | 131 | 134 | 138 | 0.6 |
| Europe | 81 | 85 | 87 | 90 | 93 | 96 | 0.6 |
| Asia | 39 | 43 | 45 | 46 | 47 | 48 | 0.8 |
| **OECD with U.S. CPP** | **238** | **252** | **258** | **265** | **272** | **280** | **0.6** |
| OECD Americas with U.S. CPP | 118 | 124 | 125 | 128 | 132 | 136 | 0.5 |
| **Non-OECD** | **311** | **375** | **413** | **451** | **491** | **533** | **1.9** |
| Europe/Eurasia | 51 | 52 | 55 | 56 | 58 | 58 | 0.5 |
| Asia | 176 | 223 | 246 | 270 | 295 | 322 | 2.2 |
| Middle East | 32 | 41 | 45 | 51 | 57 | 62 | 2.4 |
| Africa | 22 | 26 | 30 | 34 | 38 | 44 | 2.6 |
| Americas | 31 | 33 | 37 | 40 | 43 | 47 | 1.5 |
| **Total World** | **549** | **629** | **674** | **718** | **766** | **815** | **1.4** |
| **Total World with U.S. CPP** | **549** | **627** | **671** | **715** | **763** | **813** | **1.4** |

[9] U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

or IEO2016 Reference cases. However, the impact is addressed in key tables, figures, and discussions in IEO2016, based on EIA's analysis of the proposed version of the CPP rule, which was issued earlier. The *Annual Energy Outlook 2016* (AEO2016) Reference case will include the final CPP rule.

For policies outside the United States, EIA analysts assess the prospects that countries or country groups (for example, the European Union) will be able to achieve the goals or targets stated or implied in their policies. Analysts may consider the track record of countries or country groupings in meeting goals of current or past policies as an indicator of their likely success in meeting future policy targets. For example, the European Union's 20-20-20 plan is fully incorporated in EIA's projections for Organization for Economic Cooperation and Development (OECD) Europe. On the other hand, Ukraine's 2012 strategic goal for planned nuclear capacity additions is not fully implemented in the projections given that country's poor track record.

EIA attempts to be transparent about the extent to which international government policies, regulations, targets, and other statements are incorporated in the IEO projections. Where major policies have not been fully implemented in the analysis, explanations are provided for the rationale of the approaches that are used.

Much of the world increase in energy demand occurs among the developing non-OECD nations (outside the Organization for Economic Cooperation and Development),[10] where strong economic growth and expanding populations lead the increase in world energy use. Non-OECD demand for energy rises by 71% from 2012 to 2040. In contrast, in the more mature energy-consuming and slower-growing OECD economies, total energy use rises by only 18% from 2012 to 2040 (Figure 1-2).

Economic growth, along with accompanying structural changes, strongly influences world energy consumption. As countries develop and living standards improve, energy demand grows rapidly. For instance, in nations experiencing fast-paced economic growth, the share of the populace demanding improved housing—which requires more energy to construct and maintain—often increases. Increased demand for appliances and transportation equipment, and growing capacity to produce goods and services for both domestic and foreign markets, also lead to higher energy consumption. Over the past 30 years, world economic growth has been led by the non-OECD countries, accompanied by strong growth in energy demand in the region. From 1990 to 2012, real GDP grew by 4.9%/year in non-OECD countries, compared with 2.1%/year in OECD countries. In the future, the differences in economic growth rates between OECD and non-OECD nations are expected to narrow, as economic growth in non-OECD countries moderates, and as their industrial structures move from reliance mainly on production in energy-intensive industries to more service-oriented industries. In the IEO2016 Reference case, average GDP in the non-OECD region grows by 4.2%/year from 2012 to 2040, compared with 2.0%/year in the OECD (Figure 1-3).

On a worldwide basis, real gross domestic product (GDP, measured in purchasing power parity terms) grows in the IEO2016 Reference case by an average of 3.3%/year from 2012 to 2040—with non-OECD GDP growth averaging 4.2%/year and OECD GDP growth averaging 2.0%/year. Accordingly, energy consumption growth is led by non-OECD demand. Non-OECD energy consumption first surpassed the OECD total in 2007; in 2040, total energy demand in the non-OECD region exceeds the OECD total by 89%.

More than half of the projected increase in global energy consumption from 2012 to 2040 occurs among the nations of non-OECD Asia, a country grouping that includes China and India. In the Reference case, energy demand in non-OECD Asia by 83% (or, by

**Figure 1-2. World energy consumption by region, 1990–2040 (quadrillion Btu)**

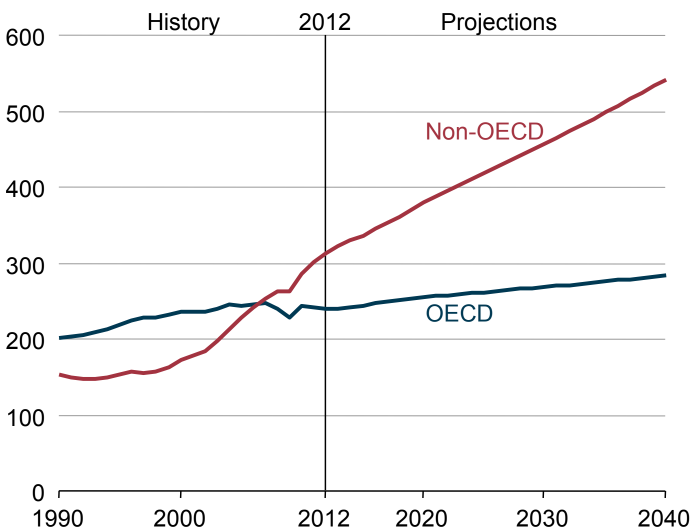
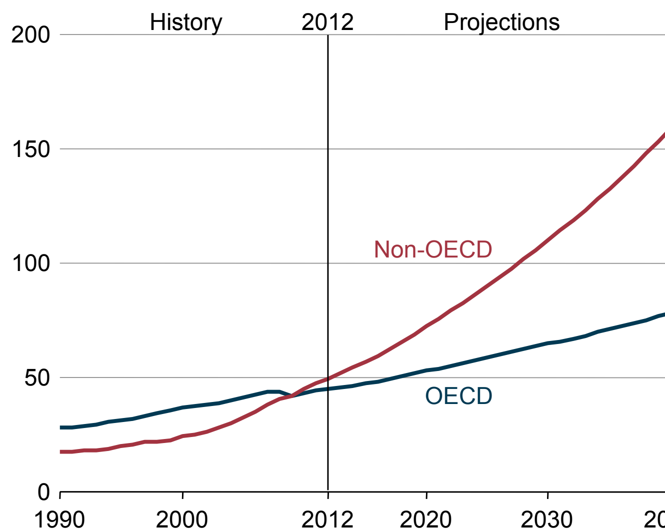



**Figure 1-3. World total gross domestic product, 1990–2040 (trillion 2010 dollars)**




[10]For consistency, OECD includes all members of the Organization for Economic Cooperation and Development as of January 1, 2016, throughout every time series presented in this publication.

146 quadrillion Btu) from 2012 to 2040. China and India, in particular, have been among the world's fastest-growing economies over much of the past decade. Although their rates of economic expansion are expected to moderate in the future, they remain important areas of growth in world energy demand throughout the 2012–40 period.

In addition to energy demand growth in non-OECD Asia, other non-OECD regions show substantial increases in energy demand in the IEO2016 Reference case (Figure 1-4). Fast-paced growth in population and access to ample domestic resources result in a total increase of 95% (30 quadrillion Btu) in the Middle East region's energy consumption from 2012 and 2040. Similarly, Africa's energy consumption more than doubles (a total increase of 22 quadrillion Btu), and energy use in the non-OECD Americas region grows by 53% (16 quadrillion Btu). The smallest total increase in energy demand in the Reference case from 2012 to 2040 among non-OECD regions is 14% for non-OECD Europe and Eurasia, including Russia, as the region's population declines and significant gains in energy efficiency are achieved by replacing old, Soviet-era capital equipment with more efficient stock.

## Outlook for world energy consumption by source

Consumption of energy from all sources increases in the IEO2016 Reference case. Concerns about energy security, effects of fossil fuel emissions on the environment, and sustained high world oil prices in the long term support expanded use of nonfossil renewable energy sources and nuclear power, as well as natural gas, which is the least carbon-intensive fossil fuel. With government policies and incentives promoting the use of nonfossil energy sources in many countries, renewable energy is the world's fastest-growing source of energy, at an average rate of 2.6%/year, while nuclear energy use increases by 2.3%/year, and natural gas use increases by 1.9%/year (Figure 1-5). Coal is the world's slowest growing form of energy in the Reference case, at an average rate of 0.6%/year (compared with an average increase of 1.4%/year in total world energy demand).

Fossil fuels continue to provide most of the world's energy in the IEO2016 Reference case: in 2040, liquid fuels, natural gas, and coal account for 78% of total world energy consumption. Petroleum and other liquid fuels remain the largest source of energy, although their share of total world marketed energy consumption declines from 33% in 2012 to 30% in 2040. Worldwide, most of the increase in liquid fuels consumption occurs in the transportation and industrial sectors, with a small increase in the commercial sector and decreases in the residential and electric power sectors. The declines in the use of liquid fuels in the residential and power sectors result from rising world oil prices, which lead to switching from liquids to alternative fuels where possible. In contrast, the use of liquid fuels in the transportation and industrial sectors increases even as their prices continue to rise. Worldwide, consumption of liquid fuels grows by 1.1%/year in the transportation sector, and by 1.0%/year in the industrial sector, from 2012 to 2040.

In the IEO2016 Reference case, the world's total natural gas consumption increases by 1.9%/year on average, from 120 trillion cubic feet (Tcf) in 2012 to 133 Tcf in 2020 and to 203 Tcf in 2040. Increasing supplies of natural gas, particularly from shale formations in the United States and Canada, and eventually elsewhere, help to supply global markets. In the future, advances in the application of horizontal drilling and hydraulic fracturing technologies, which have contributed to the rapid increase in U.S. natural gas production, are applied in other parts of the world, with the newly available natural gas resources supporting worldwide growth in natural gas consumption. From 2012 to 2040, world natural gas demand increases in all end-use sectors, with the largest increments in the electric power sector and the industrial sector, which together account for nearly 75% of the total increase in world natural gas consumption.

**Figure 1-4. Non-OECD energy consumption by region, 1990–2040 (quadrillion Btu)**

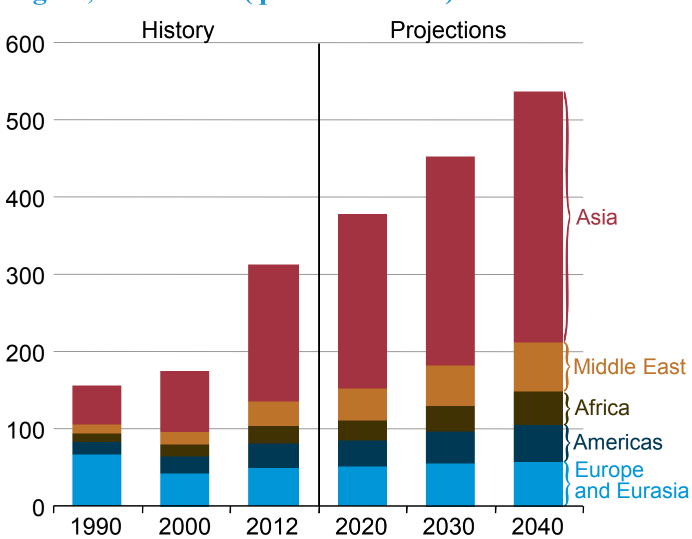
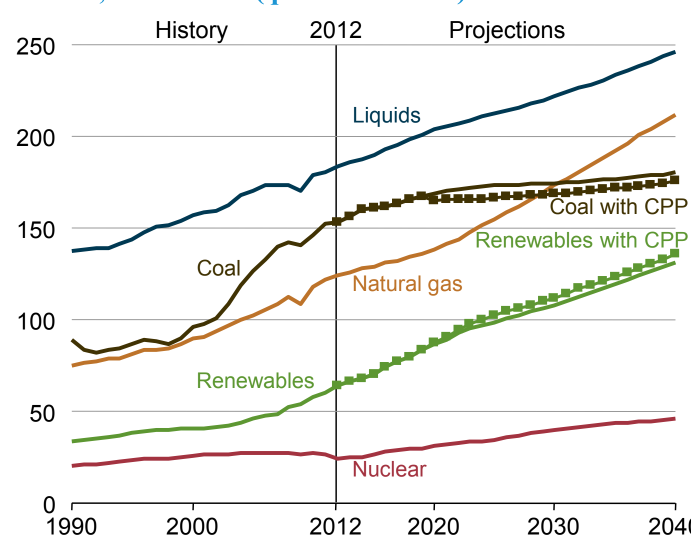



**Figure 1-5. World energy consumption by energy source, 1990–2040 (quadrillion Btu)**




Note: Dotted lines for coal and renewables show projected effects of the U.S. Clean Power Plan.

Coal is the slowest-growing energy source in the IEO2016 Reference case, with 0.6%/year average increases in total world coal consumption from 2012 to 2040, considerably slower than the 2.2%/year average over the past 30 years.[11] Coal consumption slows (or declines) in every region of the world from 2012 to 2040. In China, where coal use has increased by an average of nearly 6.0%/year over the past 30 years, the increases in the Reference case average only 0.3%/year from 2012 to 2040. China's recent moves to reduce coal as a means of addressing air pollution in major urban areas, and the government's announcement in November 2015 that the country's carbon dioxide emissions would peak by 2030, result in lower coal demand for China in the IEO2016 Reference case than in previous IEOs. Only 2 years ago, in the IEO2013 Reference case projections, coal use in China totaled 121 quadrillion Btu in 2040. In IEO2016, China's coal use reaches 88 quadrillion Btu in 2025 before declining to 83 quadrillion Btu in 2040.

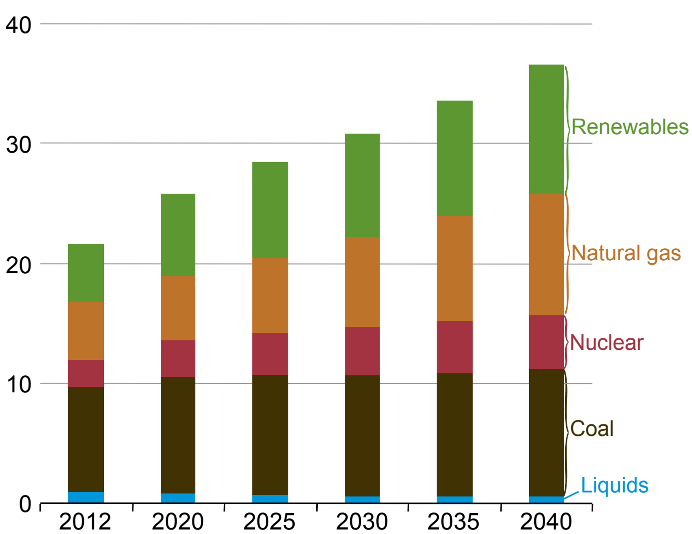
Coal consumption projections in the IEO2016 Reference case, which total 169 quadrillion Btu in 2020 and 180 quadrillion Btu in 2040, do not include the effect of the final Clean Power Plan regulations in the United States. Including the CPP would reduce world coal consumption to 165 quadrillion Btu in 2020 and to 176 quadrillion Btu in 2040, based on EIA's analysis of the CPP proposed rule.[12] EIA's analysis of the final rule is expected to show a roughly similar impact on projections of U.S. coal use.

Electricity consumption by end users grows faster than their use of other delivered energy sources in the Reference case, as has been true for the past several decades. Net electricity generation worldwide rises by 1.9%/year on average from 2012 to 2040, with the strongest growth in non-OECD countries. Increases in non-OECD electricity generation average 2.5%/year in the IEO2016 Reference case as rising living standards increase demand for home appliances and electronic devices as well as for commercial services, including hospitals, schools, office buildings, and retail and grocery stores. In the OECD nations, where infrastructures are more mature and population growth is relatively slow or declining, electric power generation increases by an average of 1.2%/year from 2012 to 2040.

Coal, which currently provides the largest share of energy for world electricity generation in the IEO2016 Reference case (Figure 1-6), declines from 40% of total generation in 2012 to 29% in 2040.[13] In addition, if the U.S. CPP were included in the projections, the coal share of world generation would be 28% in 2040. The liquid fuels share of total generation also falls in the IEO2016 Reference case, as other fuels are substituted for higher-priced liquids in the power generation sector. The liquids share of total generation falls from 5% in 2012 to less than 2% in 2040. Natural gas and renewable energy sources account for increasing shares of total generation, with the natural gas share growing from 22% in 2012 to 28% in 2040 and the renewable share growing from 22% in 2012 to 29% in 2040. If the U.S. CPP were included, the renewable share of world generation would increase to 30% in 2040. Renewable generation (including hydropower) is the fastest-growing source of electric power in the IEO2016 Reference case, rising by an average of 2.9%/year, compared with average annual increases for natural gas (2.7%), nuclear power (2.4%), and coal (0.8%). Government policies and incentives throughout the world support the rapid construction of renewable generation facilities. By 2040 renewables, natural gas, and coal each hold a similar share of global electricity generation.

Hydropower and wind are the two largest contributors to the increase in world electricity generation from renewable energy sources, together accounting for two-thirds of the total increment from 2012 to 2040. Both hydropower and wind generation increase by about 1.9 trillion kilowatthours (kWh) in the IEO2016 Reference case. Although nonhydropower resources account for most of the increase in world renewable generation, hydropower provides nearly 40% of the growth in the non-OECD region. Strong increases in non-OECD hydroelectricity generation, primarily from mid- to large-scale power plants, are expected in Brazil and in non-OECD Asia (particularly in China and India), which in combination account for more than 75% of the total increase in non-OECD hydroelectricity generation from 2012 to 2040.

**Figure 1-6. World net electricity generation by energy source, 2012–40 (trillion kilowatthours)**




Hydroelectric potential in the OECD region is much lower than in the non-OECD region, because most of the economically exploitable hydroelectric resources in OECD countries already have been developed. Except in a few cases—notably, Canada and Turkey—there are few opportunities to expand large- and mid-scale hydroelectric power projects in the OECD. Instead, most renewable energy growth in OECD countries comes from wind and solar resources. Many OECD countries, particularly those in Europe, have government policies (including feed-

[11]U.S. Energy Information Administration, International Energy Statistics database (as of September 2015), www.eia.gov/ies. World coal consumption grew from 4.3 million short tons in 1982 to 8.3 million short tons in 2012, or an average annual growth rate of 2.2%.

[12]U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

[13]This outlook does not incorporate the effect on the United States of the recently-released final clean power plant (CPP) rules. EIA's assessment of the proposed rules suggests that U.S. coal-fired generation could be reduced significantly from the IEO2016 Reference case projection.

in tariffs, tax incentives, and market share quotas) that encourage construction of wind and other nonhydropower renewable electricity facilities. In the IEO2016 Reference case, 82% of the growth in OECD renewable energy consumption is attributed to nonhydropower renewables (Figure 1-7).

Electricity generation from nuclear power worldwide increases from 2.3 trillion kWh in 2012 to 3.1 trillion kWh in 2020 and to 4.5 trillion kWh in 2040 in the IEO2016 Reference case, as concerns about energy security and greenhouse gas emissions support the development of new nuclear generating capacity. World average capacity utilization rates for nuclear power plants have continued to rise over time, from about 68% in 1980 to about 80% in 2012, and they could continue to improve in many regions. In the Reference case, virtually all of the net expansion in world installed nuclear power capacity occurs in non-OECD countries, led by China's addition of 139 gigawatts (GW) of nuclear capacity from 2012 to 2040 (Figure 1-8). Within the OECD, only South Korea has a sizable (15 GW) increase in nuclear capacity. Capacity reductions in Canada and OECD Europe, and in Japan (where nuclear capacity in 2040 in the Reference case remains below the total before the March 2011 Fukushima Daiichi nuclear disaster) more than offset the increase in South Korea's nuclear capacity. As a result, the combined capacity of all OECD nuclear power plants drops by a net 6 GW from 2012 to 2040.

## Delivered energy consumption by end-use sector

Understanding patterns in the consumption of energy delivered to end users[14] is important for the development of projections of global energy use. Outside the transportation sector, which at present is dominated by liquid fuels, the mix of energy use in the residential, commercial, and industrial sectors varies widely by region, depending on a combination of regional factors, such as the availability of energy resources; levels of economic development; and political, social, and demographic factors.

### *Buildings sector*

Energy consumed in the buildings sector, divided between residential and commercial end users, accounts for one-fifth of the total delivered energy consumed worldwide. In the IEO2016 Reference case, total world energy consumption in buildings increases by an average of 1.5%/year from 2012 to 2040.

Energy use in the residential sector is defined as the energy consumed by households, excluding transportation uses. Energy is used in the residential sector for heating, cooling, lighting, and water heating and for many other appliances and equipment. Income levels and energy prices influence the ways in which energy is consumed in the residential sector, as do various other factors, such as location, building and household characteristics, weather, equipment types and efficiencies, access to delivered energy, availability of energy sources, and energy-related policies. As a result, the types and amounts of energy use by households can vary widely within and across regions and countries.

Energy use in homes accounts for about 13% of world delivered energy consumption in 2040 in the IEO2016 Reference case. World residential energy consumption increases by 48% from 2012 to 2040, mainly as a result of growing residential sector demand in the non-OECD countries. Total non-OECD residential energy consumption increases by an average of 2.1%/year, compared with 0.6%/year in the OECD countries. Some of the fastest-growing sources of residential consumer demand are in the countries of non-OECD Asia (including China and India), as a result of strong economic growth and expanding populations in much of the

**Figure 1-7. World net electricity generation from renewable energy sources, 2012 and 2040 (trillion kilowatthours)**

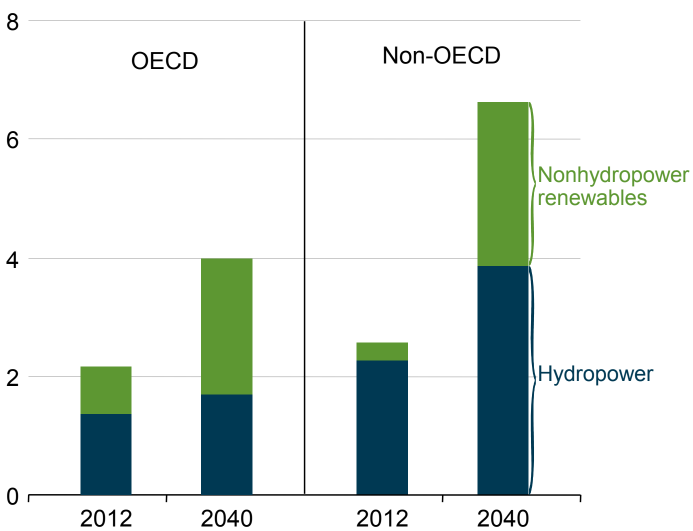
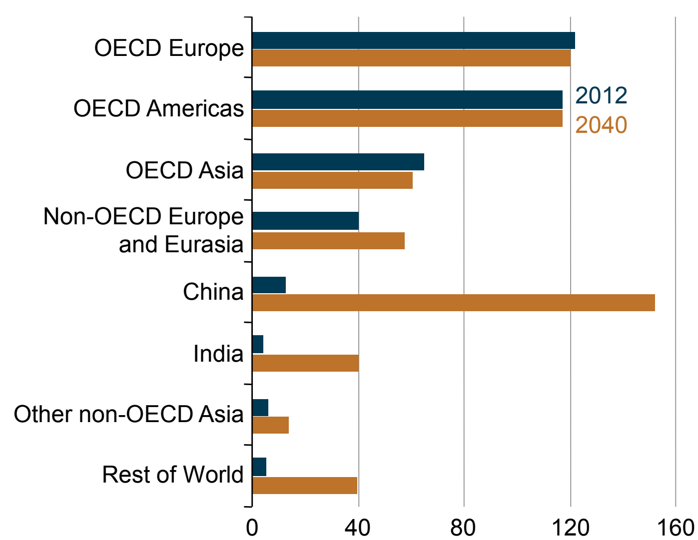



**Figure 1-8. World nuclear electricity generation capacity by region, 2012 and 2040 (gigawatts)**




[14]Delivered energy consumption in the end-use sectors consists of primary energy consumption and retail sales of electricity, excluding electrical system energy losses.

region. In 2040, the combined total residential energy use of China and India is double their 2012 total and accounts for 27% of total world residential energy consumption.

The commercial sector—often referred to as the service sector or services and institutional sector—consists of businesses, institutions, and organizations that provide services, encompassing many different types of buildings and a wide range of activities and energy-related services. In the IEO2016 Reference case, the world's total commercial sector delivered energy consumption increases by an average of 1.6%/year, and the commercial sector share of total world delivered energy use rises from about 7% in 2012 to about 8% in 2040.

Slow expansion of GDP and either slow growth or a decline in population in many OECD nations contribute to slower rates of OECD commercial energy demand growth in the Reference case. In addition, continued efficiency improvements moderate the growth of energy demand over time, as less efficient energy-using equipment is replaced with newer, more efficient stock. Among the OECD nations, delivered energy consumption in the commercial sector increases by 1.1%/year from 2012 through 2040, compared with an average of 0.6%/year for the residential sector.

In the non-OECD nations, economic activity and commerce increase rapidly, fueling additional demand for energy in the service sectors. Non-OECD population growth is also more rapid than in the OECD countries, increasing the need for education, health care, and social services and the energy required to provide them. In addition, as developing nations mature, they transition to more service-related enterprises, raising the demand for energy in the commercial sector. With substantial amounts of energy needed in the future to fuel growth in commercial buildings, total delivered commercial energy use in the non-OECD nations grows by 2.4%/year from 2012 to 2040 in the Reference case, which is more than twice the rate for the OECD commercial sector.

## EIA's handling of discrepancies in international energy data

In IEO2016, readers may notice instances where estimates of delivered liquid fuels by sector for some world regions do not add up to estimates of those regions' total delivered liquid fuels. Such discrepancies arise primarily because EIA's modeling of energy consumption by end-use sector can in some cases lead to disconnects between the historical data for total consumption of petroleum and other liquid fuels and the consumption estimates produced by the World Energy Projection System Plus (WEPS+) model. For international data, EIA's estimates of historical energy use by country are based on outside sources of information, including foreign governments, the International Energy Agency, and other organizations. Inevitably, issues of data quality, definitional differences, and timeliness arise.

IEO2016 aims to be internally consistent with all other contemporaneous EIA publications. Specifically, this report incorporates global historical data from EIA's *International Energy Statistics* (IES), as well as projections for the United States from the *Short-Term Energy Outlook* and the *Annual Energy Outlook* (AEO). The WEPS+ model used to generate IEO2016 projections is calibrated to IES data by *backtesting* for a given historical period.[15] Because the WEPS+ model includes more detail than IES on end-use consumption by sector for international regions, it can be calibrated to IES data at the fuel and region levels but not at the end-use sector level. When the sum of regional consumption from the end-use modules does not match the regional total from IES, the resulting discrepancy is reported at the region and fuel level in IEO2016.

For several IEO modeling regions, the discrepancies can be significant. Collection and reporting of international energy data are decentralized, and uncertainties typically are greater than those for U.S. energy data. Similarly, the determinants of energy demand outside the United States are less well understood than those for U.S. energy demand. As a result, such discrepancies tend to be larger in IEO2016 than in AEO2015.

### *Industrial sector*

The industrial sector encompasses manufacturing, agriculture, mining, and construction—and a wide range of activities, such as processing and assembly, space conditioning, and lighting. Industrial energy use also includes natural gas and petroleum products used as feedstocks for the production of nonenergy products, such as plastics and fertilizer. Industrial energy demand varies across regions and countries of the world, based on the level and mix of economic activity and technological development, among other factors. The industrial sector consumed 54% of global delivered energy in 2012, and its energy consumption grows by an average of 1.2%/year from 2012 to 2040 in the IEO2016 Reference case.

Industrial sector energy use in the non-OECD economies increases by 1.5%/year in the Reference case, compared with 0.5%/year in the OECD economies. The gap in growth rates reflects both faster economic expansion outside the OECD and differences in the composition of industrial sector production. Industrial operations in the OECD economies generally are more energy-efficient than those in the non-OECD economies, and the mix of industrial output is more heavily weighted toward nonenergy-intensive industry sectors in the OECD. On average, industrial energy intensity (the amount of energy consumed in the industrial sector per dollar of economic output) in non-OECD countries is much higher than in OECD countries.

[15] *Backtesting* is used to test predictive models by comparing their results with historical data.

### *Transportation sector*

Energy use in the transportation sector includes energy consumed in moving people and goods by road, rail, air, water, and pipeline. The transportation sector accounted for 25% of total world delivered energy consumption in 2012, and transportation energy use increases by 1.4%/year from 2012 to 2040 in the IEO2016 Reference case. The growth in transportation energy demand is largely a result of increases projected for the non-OECD nations, where fast-paced gains in GDP raise standards of living and, correspondingly, the demand for personal travel and freight transport to meet consumer demand for goods. Non-OECD transportation energy use increases by 2.5%/year, compared with average annual growth of 0.2% in the OECD nations, where consuming patterns are already well established, and slower growth of national economies and populations, coupled with vehicle efficiency improvements, keep transportation energy demand from increasing.

The road transport component of transportation energy use includes light-duty vehicles, such as automobiles, sport utility vehicles, minivans, small trucks, and motorbikes, as well as heavy-duty vehicles, such as large trucks used for moving freight and buses used for passenger travel. Growth rates for economic activity and population, and trends in vehicle fuel efficiency, are the key factors in transportation energy demand. Economic growth spurs increases in industrial output, which requires the movement of raw materials to manufacturing sites, as well as the movement of manufactured goods to end users. In addition, increasing demand for personal travel is a primary contributing factor to underlying increases in energy demand for transportation. Increases in urbanization and in personal incomes also contribute to increases in air travel and to motorization (more vehicles per capita) in the growing non-OECD economies.

## World economic outlook

Economic growth, along with accompanying structural changes, strongly influences world energy consumption. As countries develop and living standards improve, energy demand grows rapidly. For instance, in nations experiencing fast-paced economic growth, the share of the populace demanding improved housing—which requires more energy to construct and maintain—often increases. Increased demand for appliances and transportation equipment, and growing capacity to produce goods and services for both domestic and foreign markets, also lead to higher energy consumption. Over the past 30 years, world economic growth has been led by the non-OECD countries, accompanied by strong growth in energy demand in the region. From 1990 to 2012, real GDP grew by 4.9%/year in non-OECD countries, compared with 2.1%/year in OECD countries. In the future, the differences in economic growth rates between OECD and non-OECD nations are expected to narrow, as economic growth in non-OECD countries moderates, and as their industrial structures move from reliance mainly on production in energy-intensive industries to more service-oriented industries. In the IEO2016 Reference case, average GDP in the non-OECD region grows by 4.2%/year from 2012 to 2040, compared with 2.0%/year in the OECD.

Economic growth in the IEO2016 projections depends on increases in labor force, growth of capital stock, and improvements in productivity. Across many of the IEO regions, productivity growth—also referred to as total factor productivity (TFP) or multifactor productivity (MFP)—is especially uncertain, but it is an important determinant of income per person in the long run. However, because TFP measures things that cannot be accounted for by other inputs used in the production of goods and services, identifying the driving forces behind its growth is difficult. In general, the TFP determinants can be separated into those that focus on the creation, transfer, and use of knowledge (broadly defined), and those that build the infrastructure needed for efficient creation, transfer, and use of knowledge. Examples of the former determinants include research and development funding, and human capital. Examples of the latter determinants include the prevalence of research institutions, the condition of national infrastructures, competitiveness, and regulatory environment.

The IEO2016 assumptions about regional economic growth—measured in terms of real GDP in 2012 U.S. dollars at purchasing power parity rates—underlie the projections of regional energy demand. World economic growth has been steady in recent years, with the global economy growing by 4.0% in 2011, followed by more modest growth of 3.1% in 2012, 3.2% in 2013, and 3.3% in 2014. Such steady growth is assumed to continue in the IEO2016 Reference case, with real world GDP growth averaging 3.3%/year (on a purchasing power parity basis) from 2012 to 2040[16] (Table 1-2). The growth rate slows over the period, peaking at 3.8% in 2018, then declines to 3.0% in 2040. Global economic growth in the IEO2016 Reference case is led by the emerging economies, with growth in real GDP in the non-OECD region averaging 4.2%/year from 2012 to 2040, compared with 2.0%/year in the OECD region. Slower global economic growth after 2020 results primarily from slower growth in the emerging economies, particularly China.

### *OECD economies*

From 2012 to 2040, real GDP growth in the OECD averages 2.0%/year (on a purchasing power parity basis) in the IEO2016 Reference case (Figure 1-9). In the United States, which remains the largest OECD economic region, real GDP growth averages 2.4%/year from 2012 to 2040. Slower growth of the U.S. labor force over the projection period, as the baby boom generation retires, is partially offset by increases in productivity. Changes in productivity growth are the key source of uncertainty in the U.S. projection.

[16]The purchasing power parity exchange rate is the exchange rate at which the currency of one country is converted into that of another country to buy the same amount of goods and services.

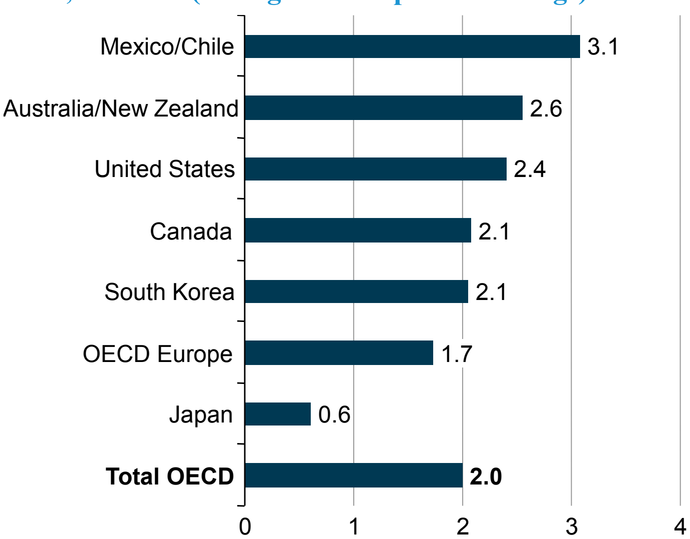
Canada's economic growth in the Reference case, at 2.1%/year from 2012 to 2040, is slower than that of the United States. Although recent declines in oil prices reduce Canadian GDP growth in the near term, prospects for the long term are relatively healthy, given Canada's record of fiscal prudence and the productive capacity of its economy. Canada has also diversified beyond commodity production, with services accounting for more than 70% of Canadian value added.[17]

Chile and Mexico are the fastest-growing OECD countries from 2012 to 2040 in the IEO2016 Reference case, with their combined GDP increasing by an average of 3.1% annually. Because the two nations are primarily exporters, especially of commodities, short-term and long-term commodity prices will substantially affect export revenues—as will fluctuations in exchange rates with major trading partners. Although both countries are well positioned for medium- to long-run growth, given their expanding working-age populations, there are also concerns about infrastructure, competitiveness (especially in Mexico), and education.

GDP growth in OECD Europe increases by an average of 1.7%/year in the IEO2016 Reference case, which is the second slowest rate among the OECD regions, after Japan. In the near term, most European countries still have to deal with the aftermath of the European financial crisis and ensuing credit issues, which have slowed recent GDP gains and depressed investment. In the longer term, OECD Europe sees moderate increases in productivity, driven by research and development and a well-educated population; however, the region's overall population growth is expected to slow, and the working-age population is projected to begin declining shortly after 2020. Increases in capital stock are moderate over the projection period.

Japan has the slowest-growing economy among the OECD regions over the projection period, averaging 0.6%/year, attributed primarily to demographic trends. Japan's population, which began to shrink in 2012, continues declining at an average annual rate of 0.4% from 2012 to 2040 in the IEO2016 Reference case. Moreover, Japan's working-age population began to decline in the mid-1990s.[18] Combining the demographic trends with relatively slow growth in Japan's capital stock and moderate increases in productivity results in the low projected rate of GDP growth from 2012 to 2040.

**Figure 1-9. OECD real gross domestic product growth rates, 2012–40 (average annual percent change)**




South Korea's economy grows by 2.1%/year on average in the IEO2016 Reference case, with its population growth (like Japan's) slowing over the projection period to an average of 0.2%/year, and the working age population beginning to decline after 2015. Increases in the country's capital stock and productivity do not make up for these demographic factors, even though capital investment remains an important part of its real GDP growth.

In Australia and New Zealand, long-term growth prospects are also relatively healthy, given their consistent track records of fiscal prudence and structural reforms aimed at maintaining competitive product and flexible labor markets. Geographically, the two countries are well positioned to

**Table 1-2. World gross domestic product by country grouping, 2012–40 (billion 2010 U.S. dollars, purchasing power parity)**

| Region | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| **OECD** | **44,769** | **52,921** | **58,772** | **64,731** | **71,026** | **78,042** | **2.0** |
| Americas | 19,080 | 23,390 | 26,557 | 29,942 | 33,569 | 37,770 | 2.5 |
| Europe | 18,638 | 21,496 | 23,621 | 25,697 | 27,809 | 30,074 | 1.7 |
| Asia | 7,051 | 8,034 | 8,575 | 9,091 | 9,647 | 10,198 | 1.3 |
| **Non-OECD** | **49,686** | **72,195** | **90,118** | **109,979** | **132,734** | **158,789** | **4.2** |
| Europe/Eurasia | 5,535 | 6,614 | 7,764 | 9,009 | 10,437 | 11,870 | 2.8 |
| Asia | 27,914 | 44,139 | 56,222 | 69,542 | 84,680 | 102,015 | 4.7 |
| Middle East | 5,072 | 6,951 | 8,578 | 10,309 | 12,164 | 14,144 | 3.7 |
| Africa | 4,561 | 6,539 | 8,295 | 10,559 | 13,467 | 17,144 | 4.8 |
| Americas | 6,604 | 7,952 | 9,259 | 10,561 | 11,985 | 13,615 | 2.6 |
| **Total World** | **94,455** | **125,115** | **148,891** | **174,711** | **203,760** | **236,831** | **3.3** |

[17]The World Bank, "Data: Services, etc., value added (% of GDP)," (2015) http://data.worldbank.org/indicator/NV.SRV.TETC.ZS.

[18]Federal Reserve Bank of St. Louis, "Economic Research: Working Age Population: Aged 15-64: All Persons for Japan" (April 29, 2015), https://research.stlouisfed.org/fred2/series/LFWA64TTJPM647S.

benefit from export market opportunities in emerging Asian countries; however, their aging populations may be one barrier to higher rates of economic growth in the medium to long term. In the IEO2016 Reference case, the combined GDP of Australia and New Zealand grows by an average of 2.6%/year from 2012 to 2040.

### *Non-OECD economies*

Real GDP growth from 2012 to 2040 in the combined non-OECD region averages 4.2%/year in the IEO2016 Reference case (Figure 1-10). Investment and exports support GDP increases in the near term, although slower growth in the advanced economies and the potential for inflation are concerns. In the medium to long term, population growth, the potential for technological advancement, and lower debt levels help to support faster economic expansion in the non-OECD region. Achieving faster economic growth will require additional infrastructure investment and improvements in regulatory and financial institutions.

India has the world's fastest-growing economy in the IEO2016 Reference case, averaging 5.5%/year from 2012 to 2040. In the shorter term, the combination of lower interest rates and moderate inflation supports increases in both consumption and investment. Additional structural reforms—such as ending regulatory impediments to the consolidation of labor-intensive industries, reforming labor markets and bankruptcy terms, and liberalizing agricultural and trade practices—will be essential for achieving the projected GDP growth rates over the longer term.

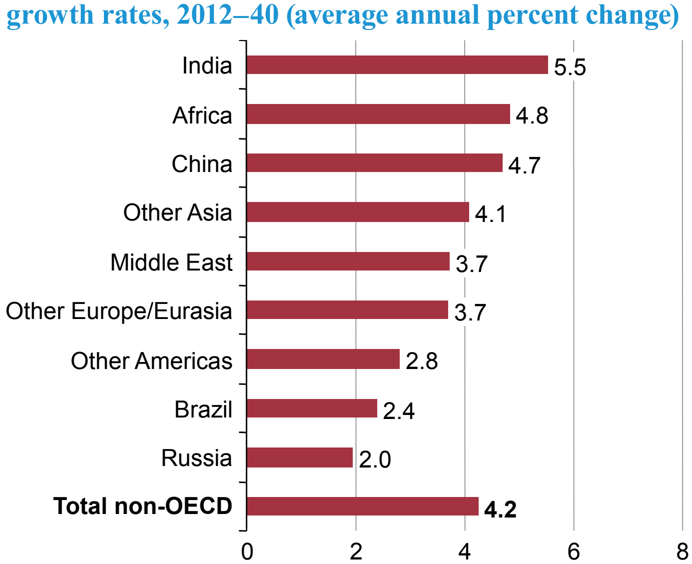
China's economic growth in 2014 was its lowest in 24 years, and it continues to slow in the IEO2016 Reference case with an average growth rate of 4.7%/year from 2012 to 2040. The slower economic growth is in part the result of demographics—China has an aging population and shrinking work force—accompanied by a slower rate of productivity that fails to make up for lower levels of investment. The fate of nonperforming loans, and the extent to which reforms are allowed to influence state-owned enterprises, both are key uncertainties in the projection for China's GDP growth. On the other hand, China's economy is expected to undergo a transition over the 2012–40 period, from being dominated by investment to achieving a better balance between consumption and investment.

Many of the other economies of non-OECD Asia have benefited from trade ties with—and are largely reliant on—China. For those that depend on exports (including Hong Kong, Indonesia, Singapore, and Taiwan), China's slowing economy is likely to slow their GDP growth in the near term. However, many non-OECD Asia countries also trade heavily with the United States, Japan, and OECD Europe, and as a result their economic performance is intertwined with demand from the advanced economies. In the long term, growth prospects in non-OECD Asia remain favorable. Excluding China and India, real GDP in non-OECD Asia grows by an average of 4.1%/year from 2012 to 2040 in the IEO2016 Reference case.

In Russia, lower oil prices and sanctions have substantially reduced the short-term prospect for economic growth. Russia also faces challenges in the longer term related to the continuing shrinkage of its labor force and population, and to the need for diversification of its economy away from its current heavy reliance on energy exports. Additionally, reforms in labor markets and state-owned enterprises will be important for long-term growth. In the IEO2016 Reference case, Russia's economy grows by an average of 2.0%/year from 2012 to 2040.

Exports also are an important component of GDP for the countries of Central Europe and the Balkans, especially given their large fiscal deficits. Banks and other entities in non-OECD Europe and Eurasia continue to face difficulties in gaining access to foreign loans, as many lending institutions have restricted cross-border loans. The restricted access to loans has lowered investment levels and may also affect future productivity. The effects were softened somewhat by higher world market prices for commodity exports over the past several years, but recent declines may slow growth in the near term. In the longer term, these countries have the potential for faster economic expansion, and economic growth in the non-OECD Europe and Eurasia region (excluding Russia) averages 3.7%/year from 2012 to 2040.

**Figure 1-10. Non-OECD real gross domestic product growth rates, 2012–40 (average annual percent change)**




Projected growth of real GDP in Brazil in IEO2016 averages 2.4%/year from 2012 to 2040 in the Reference case. This is a relatively slow rate of growth, especially for a developing country, reflecting both current economic weakness and questions about future growth. There is little doubt that Brazil has the consumers to generate demand for goods and services, but the supply side of its economy appears to constrain economic growth. Structural reforms, particularly to state-owned enterprises and labor markets, will be important for Brazil to generate long-term growth.

Outside Brazil, investment in the non-OECD Americas is constrained by policy uncertainty, and commodity exports are not expected to provide the level of government revenue that they have in the recent past. The proximity of the region to the United States and the trade relationships of its national economies with the U.S. economy suggest that the region's growth will be linked, in part, to that of the United States. Most countries in the region have flexible exchange rates, positive trade balances, and relatively low fiscal deficits and public debts. Regional inflation is lower than it was in the mid-1990s, and a relatively young labor force supports the region's economic growth prospects. Real GDP in the non-OECD Americas (excluding Brazil) increases by an average of 2.8%/year from 2012 to 2040 in the IEO2016 Reference case.

Africa's combined real GDP increases by 4.8%/year on average from 2012 to 2040 in the IEO2016 Reference case. However, economic prospects for African countries vary widely across the continent. Africa is rich in natural resources, including oil, natural gas, and coal. Overall, the region has a relatively young population, with potential for labor force growth. Except for South Africa, many sub-Saharan African countries have seen recent annual growth rates between 4% and 10%, with Ethiopia experiencing the highest growth in 2013, at 10.4%.[19] Expanding domestic markets and increasing regional integration will support long-term growth, although Africa faces many challenges. Oil exports from northern Africa and most of sub-Saharan Africa are slowing because of lower world oil prices. Moreover, both economic and political factors—such as low savings and investment rates, lack of strong economic and political institutions, limited quantity and quality of infrastructure and human capital, negative perceptions on the part of international investors, protracted civil unrest and political disturbances, and the impacts of various diseases—present formidable obstacles to the economies of some African countries.

Economic growth in the Middle East region averages 3.7%/year from 2012 to 2040 in the IEO2016 Reference case. This region is challenged by continuing geopolitical instability that discourages foreign investment, as well as heavy reliance on commodity exports for economic growth. In recent years, rising oil production and prices have helped to boost economic growth in the oil-exporting countries of the Middle East, many of which have also benefited from spillover effects on trade, tourism, and financial flows from the region's oil exports. In the short run, political instabilities combined with lower expected oil revenues are likely to constrain growth. Over the long run, however, robust population growth, combined with the potential for rising oil prices and rebounding demand for the region's export commodities, create favorable prospects for economic growth in the Middle East. The medium to long term still presents many challenges. Political turmoil and domestic unrest threaten to depress consumer confidence and investment. Training and educating the labor force, and the dependence of many Middle East countries on commodity exports for growth, also are key challenges for regional economic growth prospects, with reliance on oil and natural gas revenues continuing through much of the projection period.

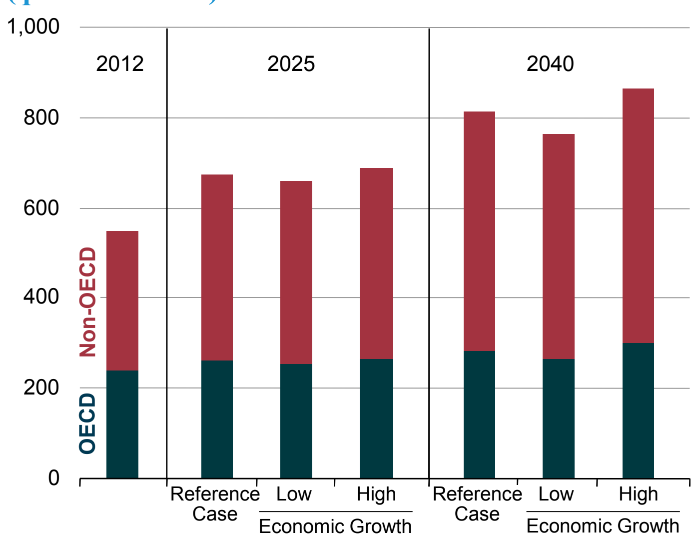
## Alternative cases in IEO2016

### *Alternative economic growth cases*

Expectations for future rates of economic growth are a major source of uncertainty in the IEO2016 projections. To illustrate the uncertainties associated with economic growth trends, IEO2016 includes a High Economic Growth case and a Low Economic Growth case in addition to the Reference case. The two alternative growth cases use different assumptions about future economic growth paths, while maintaining the oil price path of the IEO2016 Reference case.

In the High Economic Growth case, real GDP in the OECD increases by 2.3%/year from 2012 to 2040, as compared with 2.0%/year in the Reference case. Similarly, the High Economic Growth case assumes GDP growth of 4.5%/year in the non-OECD region as a whole, compared with 4.2%/year in the Reference case. In the Low Economic Growth case, OECD GDP increases by 1.6%/year, or 0.4 percentage points lower than in the Reference case. GDP growth in the non-OECD region is assumed to average 3.9%/year in the Low Economic Growth case, or 0.3 percentage points lower than in the Reference case.

**Figure 1-11. World energy consumption by region in three economic growth cases, 2012, 2025, and 2040 (quadrillion Btu)**




In the IEO2016 Reference case, world energy consumption totals 815 quadrillion Btu in 2040—282 quadrillion Btu in the OECD countries and 533 quadrillion Btu in the non-OECD countries. In the High Economic Growth case, world energy use in 2040 is 862 quadrillion Btu—47 quadrillion Btu (about 24 million barrels oil equivalent per day) higher than in the Reference case (Figure 1-11). In the Low Economic Growth Case, world energy use in 2040 totals 764 quadrillion Btu—51 quadrillion Btu (about 25 million barrels oil equivalent per day) lower than in the Reference case. Thus, the projections for 2040 in the High and Low Economic Growth cases span a range of uncertainty equal to 98 quadrillion Btu, which is roughly equal to total U.S. energy consumption in 2012.

[19] IHS Economics, *World Overview: Fourth-quarter 2015* (2015), p. 69, https://www.ihs.com (subscription site).

### *Alternative oil price cases*

Expectations for future world oil prices are another key source of uncertainty in the IEO2016 projections. To illustrate the uncertainties associated with future oil prices, IEO2016 includes a Low Oil Price case and a High Oil Price case in addition to the Reference case. The two alternative oil price cases use different assumptions about future oil prices, based on four key factors: Organization of the Petroleum Exporting Countries (OPEC) investment and production decisions; the economics of non-OPEC petroleum liquids supply; the economics of other liquids supply; and world demand for petroleum and other liquids. Each case represents one of many possible combinations of supply and demand that would result in the same price path.

Real oil prices (in 2013 dollars) have fallen precipitously since 2011, from about $115 per barrel to about $50 per barrel in 2015 (according to EIA's March 2016 Short-Term Energy Outlook). Prices are expected to recover over the course of the projection period, reaching $141 per barrel in 2040. Total world spending on oil grows 1.6%/year over the projection, well below the 3.3%/year rate of income growth over the same period, suggesting that a smaller share of income would be required to cover consumer oil needs. The IEO2016 Reference case reflects mid-range expectations for exploration and development costs and accessibility of oil resources. The Reference case also assumes that OPEC producers will choose to maintain their share at 39% to 43% of the global liquid fuels market. In the Reference case, OECD consumption of petroleum and other liquids increases from 45.5 million barrels per day (b/d) in 2012 to 46.1 million b/d in 2040, and non-OECD consumption of petroleum and other liquids increases from 44.8 b/d to 74.8 million b/d. Total energy consumption in the Reference case rises to 815 quadrillion Btu in 2040.

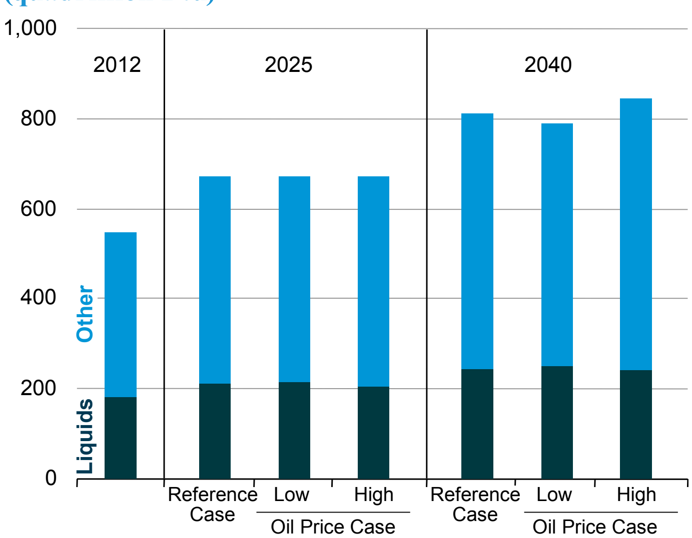
In the Low Oil Price case, crude oil prices are $76 per barrel (2013 dollars) in 2040. GDP growth in the non-OECD countries averages 3.9%/year from 2012 to 2040, compared with Reference case growth of 4.2%/year. A combination of lower economic activity and lower prices results in a level of non-OECD liquid fuels consumption in 2040 close to that in the Reference case. Even in a scenario assuming low economic growth (which translates to lower energy demand, with non-OECD energy demand in 2040 24 quadrillion Btu lower than in the Reference case), the lower prices encourage consumers to use relatively cheap liquid fuels rather than other forms of energy.

In contrast to the non-OECD, economic growth in the OECD regions is essentially the same in the Low Oil Price case as in the Reference case, and total OECD energy consumption in 2040 also is about the same as in the Reference case. However, lower oil prices encourage consumers to use more liquid fuels. OECD nations consume 48.4 million b/d of oil in 2040 in the Low Oil Price case, compared to 46.1 million b/d in the Reference case.

On the supply side, production in OPEC countries is above the Reference case level in the Low Oil Price case, obtaining a 48% share of total world petroleum and other liquids production in 2040. Oil production in the non-OPEC countries is lower than in the Reference case, however, because their more expensive resources cannot be brought to market economically.

In the High Oil Price case, oil prices increase to $252 per barrel (2013 dollars) in 2040. GDP growth in the non-OECD countries averages 4.5%/year from 2012 to 2040 in the High Oil Price case, compared with 4.2%/year in the Reference case. The combination of high economic activity and high prices results in non-OECD liquids consumption that is about the same as in the Reference case (Figure 1-12). Although higher economic activity increases non-OECD demand for total energy (total non-OECD energy consumption is about 32 quadrillion Btu higher in the High Oil Price case than in the Reference case), the higher costs for liquid fuels encourage consumers to use other energy sources.

**Figure 1-12. World energy consumption by fuel in three oil price cases, 2012, 2025, and 2040 (quadrillion Btu)**




OECD economic growth in the High Oil Price case is unchanged from the Reference case, and as a result total energy demand is similar in the two cases. The higher oil prices, combined with the same level of economic activity as in the IEO2016 Reference case, cause OECD consumers to implement improved efficiency measures and switch to less expensive fuels where possible. In 2040, OECD regions consume 44.1 million b/d in the High Oil Price case, compared with 46.1 million b/d in the Reference case. On the supply side, oil production in the OPEC countries is lower in the High Oil Price case, and their market share declines to 34% in 2040. However, higher world oil prices allow non-OPEC countries to increase production from resources that are more expensive to produce, and the economics of nonpetroleum liquids also benefit from the higher prices.

## Chapter 2

# Petroleum and other liquid fuels

## Overview

In the *International Energy Outlook 2016* (IEO2016) Reference case, worldwide consumption of petroleum and other liquid fuels increases from 90 million barrels per day (b/d) in 2012 to 100 million b/d in 2020 and 121 million b/d in 2040. Much of the growth in world liquid fuels consumption is projected for the emerging, non-Organization for Economic Cooperation and Development (non-OECD) economies of Asia, the Middle East, and Africa, where strong economic growth and rising populations increase the demand for those fuels. In contrast, demand for liquid fuels in the United States, OECD Europe, and other regions with well-established liquids markets grows slowly or declines from 2012 to 2040. After a long period of sustained high oil prices, conservation and efficiency improvement measures have reduced or slowed the growth of liquid fuels use among OECD consumers and, in the future, will help to temper demand growth in non-OECD countries as well.

To satisfy rising demand for liquid fuels in the IEO2016 Reference case, liquids production increases by 31 million b/d over the 2012–40 period. IEO2016 projections of future liquid fuels balances include two broad categories: crude oil and lease condensate, and other liquid fuels. Crude oil and lease condensate includes: reservoired oil (often referred to in the trade press as conventional oil), tight oil (shale oil), extra-heavy crude oil, field condensate, and bitumen (i.e., oil sands, either diluted or upgraded). Other liquid fuels refers to natural gas plant liquids (NGPL), biofuels, including biomass-to-liquids (BTL), gas-to-liquids (GTL), coal-to-liquids (CTL), kerogen (i.e., oil shale), and refinery gain.[20]

The benchmark oil price in IEO2016 is based on spot prices for North Sea Brent crude oil, which is an international standard for light sweet crude oil. The West Texas Intermediate (WTI) spot price is generally lower than the North Sea Brent price. The U.S. Energy Information Administration (EIA) expects the price spread between Brent and WTI to range between $0 per barrel ($0/b) and $10/b, and will continue to report WTI prices (a critical reference point for the value of growing production in the U.S. Midcontinent) as well as the imported refiner acquisition cost for crude oil (IRAC). The December 2015 decision by the U.S. Congress to remove restrictions on U.S. crude oil exports also has the potential to narrow the spread between the Brent price and the price of domestic production streams under certain cases involving high levels of U.S. crude oil production.[21]

Growing liquids supplies in North America—especially from the United States and Canada—brought almost 7 million b/d of additional liquid fuels to market between 2008 and 2015. That increase has been offset only partially by supply disruptions in other oil-producing regions, notably North Africa and the Middle East. Over the past two years, unplanned crude oil production outages averaged 3.2 million b/d, according to EIA estimates, and amounted to 3.4 million b/d in November 2015.[22] Organization of the Petroleum Exporting Countries (OPEC) member countries Libya, Iraq, and Iran and non-OPEC countries South Sudan and Syria have accounted for a sizeable portion of the unplanned outages. It is difficult to predict when supplies from those nations may return, given their substantial geopolitical risks, which adds considerable uncertainty to the projections.

Global liquid fuels production exceeded consumption beginning in 2014 and reached 95 million b/d in 2015. The surplus production went into storage, swelling OECD inventories to 2.7 billion barrels in November 2015. Oil markets are expected to remain oversupplied in the short term, keeping EIA's forecast for annual average prices below $50/b[23] through at least 2017.

In previous instances of oil market oversupply, OPEC members have cut production to stabilize or increase prices. However, Saudi Arabia, the only member with substantial spare capacity, is no longer willing to bear the burden of production cuts alone, and since prices began falling in mid-2014, OPEC members have not acted together to cut production. Thus, OPEC production has remained stable and even increased, as OPEC members have attempted both to maximize revenue in the near term and to preserve market share. The national economies of many OPEC members are largely dependent on oil revenues, which already have been cut by the price drop, and OPEC producers have so far been unwilling to risk further revenue losses by decreasing production.

Four main factors could provide incentives for a sustained increase in world liquids production: (1) competition among OPEC member countries for market share; (2) revenue requirements of liquids-exporting countries; (3) decreasing service costs; and (4) further technology advances that lower the cost and raise recovery rates for tight oil development.

The IEO2016 uses price paths from the *Annual Energy Outlook 2015* (AEO2015) Reference case, the AEO2015 Low Oil Price case, and the AEO2015 High Oil Price case, except for adjustments to the first few years that were incorporated to reflect the continued declines in crude oil prices that have occurred since the AEO2015 was published. Oil prices observed in 2015 and into 2016 more closely resemble prices in the AEO2015 Low Oil Price case than those in the AEO2015 Reference case. However, oil prices are expected to return to the AEO2015 Reference case path in the midterm when demand for liquid fuels returns to the growth rates projected in the IEO2016 Reference case.

[20]The terms biofuels, GTL, CTL, and kerogen are used in the text of this chapter because they are common terms; however, in the tables a more uniform nomenclature is employed: liquids from renewable sources, liquids from natural gas, liquids from coal, and liquids from kerogen, respectively.

[21]U.S. Energy Information Administration, *Effects of Removing Restrictions on U.S. Crude Oil Exports* (Washington, DC: September 2015), http://www.eia.gov/analysis/requests/crude-exports/.

[22]U.S. Energy Information Administration, *Short-Term Energy Outlook* (Washington, DC: December 2015), Figures 35 and 36, www.eia.gov/forecasts/STEO.

[23]Unless otherwise noted, all prices are reported in inflation-adjusted 2013 U.S. dollars.

In response to low oil prices, which have reduced expectations of future revenue (and thus expected profits), capital expenditures for investment in future production potential have been delayed or canceled. However, many OPEC and non-OPEC large capital investment projects scheduled to be completed over the next several years will continue as planned. However, investment is likely to continue slowing to a point at which producers (outside of tight oil plays), which provide over 90% of world crude and lease condensate supply will be unable to respond quickly to future growth in demand for liquids. As a result, prices are expected to return to the range of $80/b within the next decade. If supply growth slows as a result of underinvestment, a sustained period of higher prices may be required to induce additional capital back into the market. Even then, long project timelines will delay the reentry of some production from noncontinuous resources into the market.

World demand for liquid fuels has also been a key factor in the low world oil prices of the past few years. In non-OECD countries, strong growth of liquids demand in the early to mid-2000s has moderated substantially as economic growth in key economies, including China, India, and Brazil, has slowed. Liquids consumption among OECD countries, which reached 50 million b/d in 2005, has been trending downward generally since that time, reflecting both growing energy efficiency in the transportation sector and a lull in demand associated with slow economic growth. However, even with those trends tending to dampen demand growth, world liquid fuels consumption rises by an annual average of 1.1 million b/d in the IEO2016 Reference case.

Key influences on consumption and production are price trends and the reactions of consumers and producers to those trends, which in turn influence future prices. EIA has developed three price cases to examine a range of potential interactions of supply, demand, and prices in world liquid fuels markets: the IEO2016 Reference case and alternative Low Oil Price case and High Oil Price case (Figure 2-1 and Table 2-1). Although the three oil price cases represent a wide range of future market scenarios, they do not capture all possible outcomes, and they are not intended to represent a measure of uncertainty. Because EIA's oil price paths represent market equilibrium between supply and demand, they do not show the price volatility[24] that occurs over days, months, or years.

In the IEO2016 Reference case, world consumption of petroleum and other liquid fuels increases from 90 million b/d in 2012 to 100 million b/d in 2020 and 121 million b/d in 2040. Compared with the IEO2014, the IEO2016 incorporates a smaller increase in production from non-OPEC producers, particularly the United States, because of the effects of the drop in the oil prices that began in mid-2014. The IEO2016 Reference case assumes that OPEC countries maintain or increase their combined market share of world liquid fuels production rather than cut production. Total OPEC liquid fuels production represents between 39% and 43% of total world production throughout the projection.

In comparison with the IEO2014, production of tight oil is particularly affected by the recent drop in oil prices. Still, the largest new supplies of tight oil are projected to come from the United States—with Canada, Russia, and Argentina, among other countries, also beginning to produce tight oil in the IEO2016 Reference case. In 2040, total production of tight oil outside the United States remains below U.S. production in the IEO2016 Reference case (Figure 2-2).

**Figure 2-1. North Sea Brent crude oil spot prices in three cases, 1990–2040 (2013 dollars per barrel)**

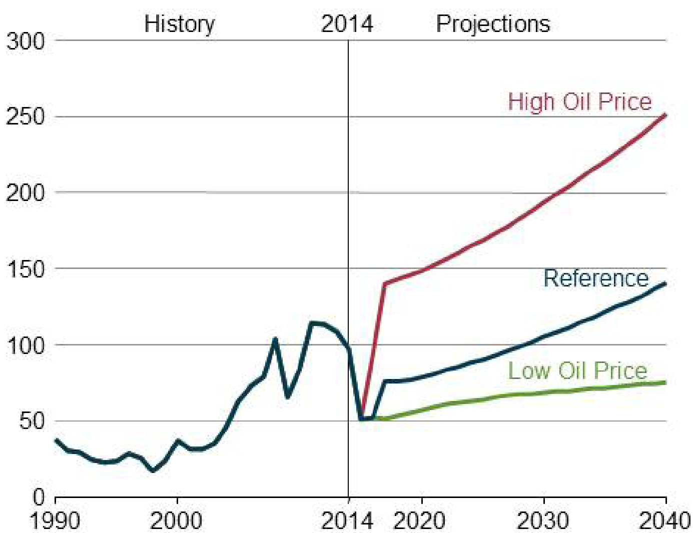
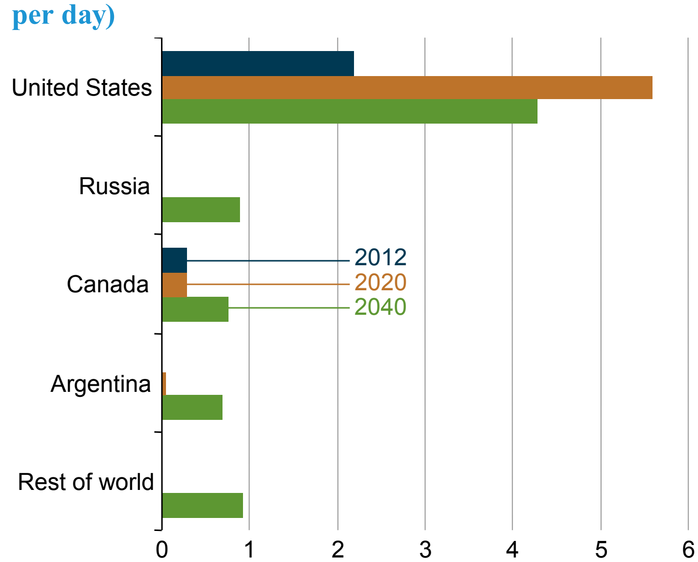



**Table 2-1. North Sea Brent crude oil spot prices in three cases, 2012–40 (2013 dollars per barrel)**

| Year | Reference | Low Oil Price | High Oil Price |
|---|---|---|---|
| 2012 | 113 | 113 | 113 |
| 2020 | 79 | 58 | 149 |
| 2025 | 91 | 64 | 169 |
| 2030 | 106 | 69 | 194 |
| 2035 | 122 | 72 | 221 |
| 2040 | 141 | 76 | 252 |

**Figure 2-2. World tight oil production in the IEO2016 Reference case, 2012, 2020, and 2040 (million barrels per day)**

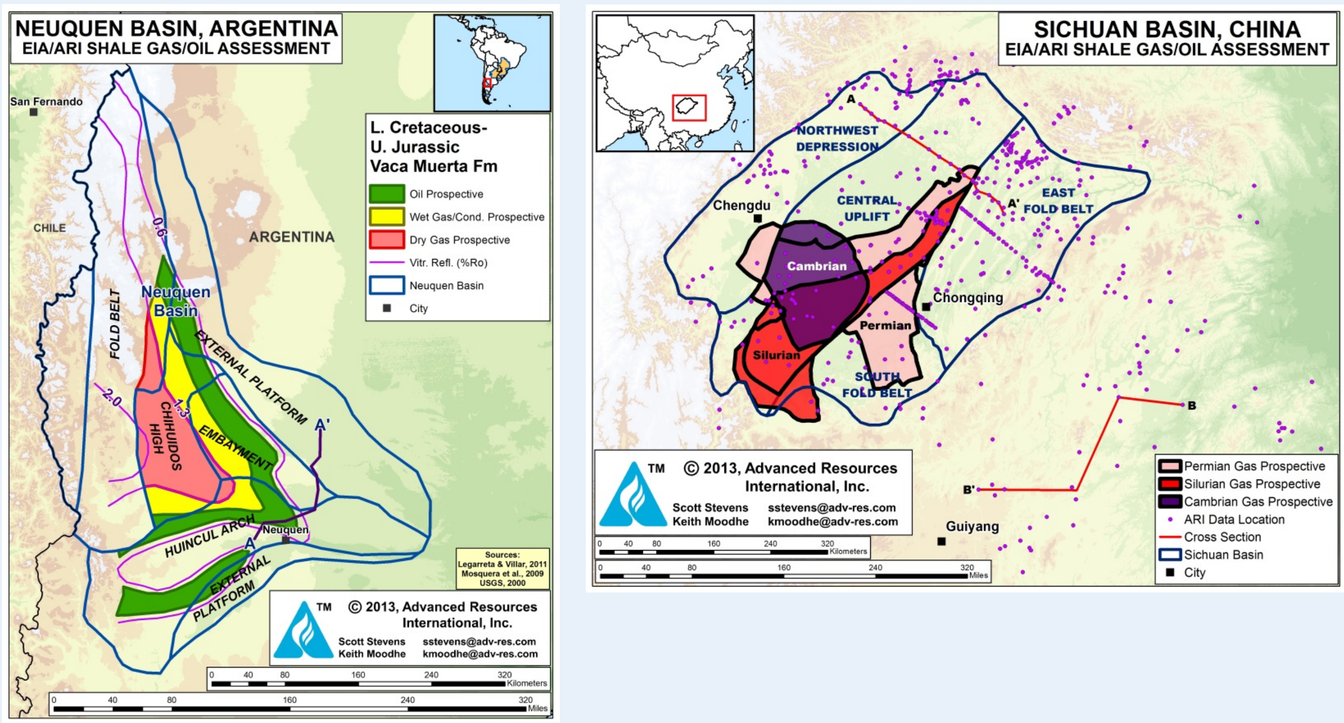



[24]Price volatility is a measure of price risk, often expressed as the degree of variation in a price series over time, as measured by the standard deviation of returns (i.e., percentage price changes). The price changes do not have to be measured on a daily basis and annualized. The price changes could be measured weekly, monthly, or even annually and then annualized.

## Shale oil and tight gas: Recent developments outside North America

In 2014, only four countries—the United States, Canada, Argentina, and China—were producing commercial volumes of either natural gas from shale formations (shale gas) or crude oil from shale or other tight formations (tight oil). Since the beginning of 2014, China has drilled more than 200 shale gas and tight oil wells, and Argentina has drilled more than 275 shale gas and tight oil wells. Those two countries led shale resource development outside North America in the first half of 2015, and both have the potential to increase production significantly (Figure 2-3).[25] In addition, Algeria, Australia, Colombia, Mexico, Poland, and Russia also began exploring and producing hydrocarbons from shale and other tight resources in 2015, but they are still short of reaching commercial production.

**Figure 2-3. EIA/ARI assessments of shale gas and tight oil resources in Argentina's Nequen Basin and China's Sichuan Basin**




In Argentina, many international companies hold leases and have drilled wells in shale formations. Much of the initial activity has targeted shale oil and natural gas in the Neuquen Basin's Vaca Muerta Shale formation, located in west-central Argentina. National energy company Yacimientos Petroliferos Fiscales (YPF), the largest shale operator in the country, reported production in April 2015 of 22,900 b/d of oil and 67 million cubic feet per day (MMcf/d) of natural gas from three joint ventures in Vaca Muerta: one with Chevron at the Loma Campana field, a second with Dow Chemical at the El Orejano field, and a third with Petronas at La Amarga Chica field. In addition, China's national oil company Sinopec and Russia's national oil company Gazprom have recently signed a memorandum of understanding with YPF for the joint development of shale resources from the same basin.

China has identified the Longmaxi formation in the Sichuan Basin, located in south-central China, as its initial shale gas exploration and development objective. Although several international companies are active in China, much of the early effort has been led by two of China's national oil companies—Sinopec and PetroChina (owned by the China National Petroleum Corporation [CNPC]). According to China's Ministry of Land and Resources, the two companies are on schedule to reach 600 MMcf/d of shale gas production by the end of 2015. Sinopec has a commercial-scale effort underway at the Fuling Shale gas field in the Sichuan Basin, currently producing 130 MMcf/d. By the end of 2014, Sinopec had completed 75 test wells at the Fuling field, with plans to drill an additional 253 wells. CNPC has drilled 125 shale wells and brought 74 of them into production and is scheduled to produce 250 MMcf/d of shale gas by the end of 2015.

Production of other liquids increases by an average of 1.5%/year in the IEO2016 Reference case—50% faster than crude and lease condensate production. The growth in other liquid supplies is attributed in part to the coproducts of natural gas production (i.e., NGPL) and to government policies aimed at increasing the use of alternative liquid fuels in the transportation sector. Other liquids account for between 16% and 18% of total liquid supplies throughout the projection.

[25]EIA/ARI 2013 assessments noted large shale deposits in China and Argentina. See U.S. Energy Information Administration, "World Shale Resource Assessments," http://www.eia.gov/analysis/studies/worldshalegas/ (updated September 24, 2015), and *Technically Recoverable Shale Gas and Shale Oil Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Washington, DC: June 13, 2013), http://www.eia.gov/analysis/studies/worldshalegas/archive/2013/pdf/fullreport_2013.pdf.

The High Oil Price case assumes faster economic growth among emerging non-OECD nations that contributes to higher world demand for petroleum and other liquid fuels. On the supply side, the High Oil Price case assumes less upstream investment by OPEC and a return to cartel-like behavior, and it assumes higher non-OPEC exploration and development costs. As a result, the average spot market price for Brent crude oil rises to $252/b in 2040, or 78% above the IEO2016 Reference case price in 2040.

The reverse is true in the Low Oil Price case. Slower economic growth leads to lower non-OECD demand for liquid fuels, while higher upstream investment and production and non-cartel behavior in OPEC, as well as lower non-OPEC exploration and development costs, contribute to increased supply from both OPEC and non-OPEC countries. As a result, the Brent spot price rises more slowly than in the IEO2016 Reference case, to $76/b in 2040, or 47% below the IEO2016 Reference case price in 2040.

The discussion presented here provides an overview of both the production and consumption of liquid fuels in the three price cases, as summarized in the notional supply and demand curves for 2040 shown in Figure 2-4. The oil price path in each of the three cases is derived from an internally consistent, illustrative scenario of supply and demand. However, other combinations of supply and/or demand could result in similar paths, and EIA does not evaluate the likelihood of either the price paths themselves or the scenarios upon which they are based. Each price case represents one of potentially many combinations of supply and demand that would result in the same price path. Because each case represents a potentially feasible equilibrium outcome, EIA does not assign probabilities to any of the oil price cases and does not consider that these three cases represent the range of all possible outcomes. The following section reviews each of the three price cases, their assumptions and indicative trends, and the potential effects of each set of factors on future liquids markets.

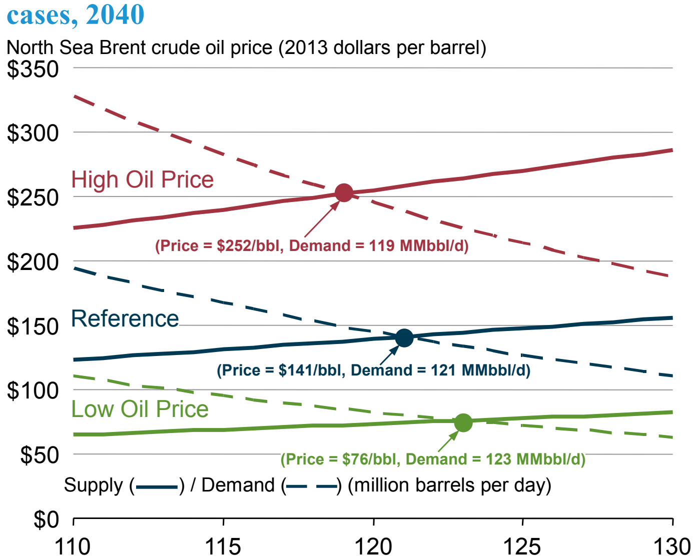
## IEO2016 Reference case

The IEO2016 Reference case reflects global oil market events through the end of 2015. Over the past two years, growth in U.S. crude oil production, along with the late-2014 drop in global crude oil prices, has altered the economics of the oil market. The new market conditions are assumed to continue in the IEO2016 Reference case, with the average Brent price dropping from $113/b in 2012 to below $50/b in 2015. After 2017, growth in demand from non-OECD countries results in a return to higher world oil prices, and the Brent price rises to $141/b in 2040.

### *World petroleum and other liquid fuels consumption*

In the IEO2016 Reference case, world liquid fuels consumption increases by about one-third (31 million b/d), from 90 million b/d in 2012 to 121 million b/d in 2040. In the medium to long term, oil prices rise as demand from the emerging, non-OECD economies continues to grow, especially in the transportation sector and also in the industrial sector. Long-term sustained increases in oil prices encourage consumers outside the transportation and industrial sectors to shift away from liquid fuels to more cost-competitive fuels wherever possible. The largest decrease in liquids consumption occurs in the electric power sector, where renewable fuels, natural gas, and nuclear power are substituted for liquids in many parts of the world.

**Figure 2-4. Liquid fuels supply and demand (million barrels per day) and North Sea Brent crude oil equilibrium prices (2013 dollars per barrel) in three cases, 2040**




Economic growth is among the most important factors to be considered in projecting changes in world energy consumption. In the IEO2016, assumptions about regional economic growth—measured in terms of real GDP expressed in purchasing power parity[26]—underlie the projections of regional demand for liquid fuels. World GDP increases by 3.3%/year from 2012 to 2040 in the IEO2016 Reference case, slightly lower than the average 3.5%/year increase in GDP that occurred between 1990 and 2012. Over the projection, economic growth in the non-OECD regions, averaging 4.2%/year, exceeds the OECD average of 2.0%/year.

Non-OECD regions account for essentially all the growth in liquid fuels consumption in the IEO2016 Reference case (Figure 2-7 and Table 2-2). In particular, non-OECD Asia and the Middle East account for about 75% of the world increase in liquids consumption from 2012 to 2040, with Africa and the non-OECD Americas each accounting for about 10% of the world increase (Figure 2-8). Fast-paced economic expansion among the non-OECD regions drives the increase in demand for liquid fuels, as strong growth in income per capita results in increased demand for personal and freight transportation, as well as demand for energy in the industrial sector.

[26]Purchasing power parity (PPP) compares different currencies through a market basket of goods approach. Two currencies are in PPP when a market basket of goods (taking exchange rates into account) is priced the same in both countries. See Investopedia LLC, http://www.investopedia.com/video/play/purchasing-power-parity-ppp/ (2016) and The Economist Newspaper Ltd., http://www.economist.com/content/big-mac-index.

## Effects of regulation on world demand for residual fuel oil

Throughout the world, residual fuel oil (RFO) is used in many sectors, including in marine transportation, power generation, in commercial furnaces and boilers, and in various industrial processes. Also, in some areas RFO is used as a relatively low-cost fuel for space heating. RFO is one of several residuals that remain after lighter materials, including gasoline and distillate, are distilled from crude oil. RFO contains large amounts of contaminants, including sulfur, nitrogen, and heavy metals. Because of its high viscosity, RFO generally is either blended with lighter streams or heated to ensure that it can be pumped.

RFO plays an important role in the global market for liquid fuels because its price is normally below that of other liquids. However, health and environmental concerns related to the high sulfur content of RFO have led to new policies and regulations that have significantly lowered expectations for its use in the future (Figure 2-5). As demand for RFO declines, refining upgrades will be needed to convert residual material to lighter, cleaner products.

Large reductions in demand for RFO are likely to come from decreases in its use for power generation and for space heating. In the power sector, the cost of pollution controls, maintenance, and RFO heating often offset the lower cost of RFO in comparison with natural gas and other more expensive fuels. Consequently, power sector demand for RFO, especially in industrialized countries, is expected to decrease, although it may continue to serve as a transitional fuel in the power sectors of non-OECD countries that may be more sensitive to price and less sensitive to environmental and health implications. Additional significant reductions in RFO demand could come from the implementation of rules set by Annex VI of the International Maritime Organization through the International Convention of Pollution from Ships (Marpol).[27] Since 2012, Marpol regulations have required controls on emissions of sulfur and nitrogen oxides worldwide. The regulations are based on emissions associated with fuel combustion rather than on the fuels themselves. As a result, some marine transportation operators are considering the use of liquefied natural gas (LNG) as an alternative fuel for ships operating along routes where LNG is available.

Because few refineries are capable of removing sulfur from RFO, Marpol compliance is likely to be achieved by two approaches: using fuels with lower sulfur content (such as marine gasoil and intermediate fuel oil) and using scrubbers or other technologies to remove sulfur from the exhaust of combustion processes. The levels stipulated by the Marpol regulations can be met by using RFO with sulfur levels of no more than 3.5%. The rules also set more stringent requirements—consistent with RFO sulfur levels of no more than 0.1%—in designated Emissions Control Areas (ECAs), which include the North Sea, the Baltic Sea, and the coastal areas of North America and the Caribbean Sea. A 2016 study is intended to evaluate the probable availability and pricing of various compliance options for the use of RFO in non-ECA areas.[28] The study should yield a decision, no later than 2018, on when the implementation of RFO reduction standards establishing sulfur emissions levels of no more than 0.5% will go into effect—either in 2020 or in 2025 (Figure 2-6).

**Figure 2-5. World consumption of residual fuel oil, 1986–2012 (million barrels per day)**

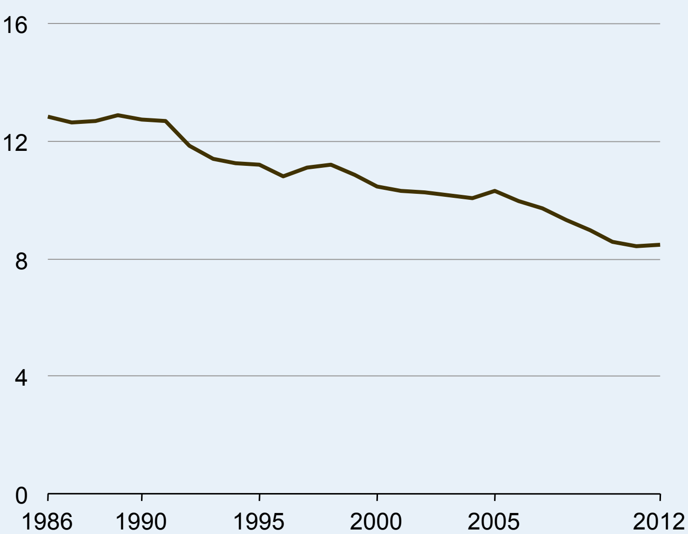
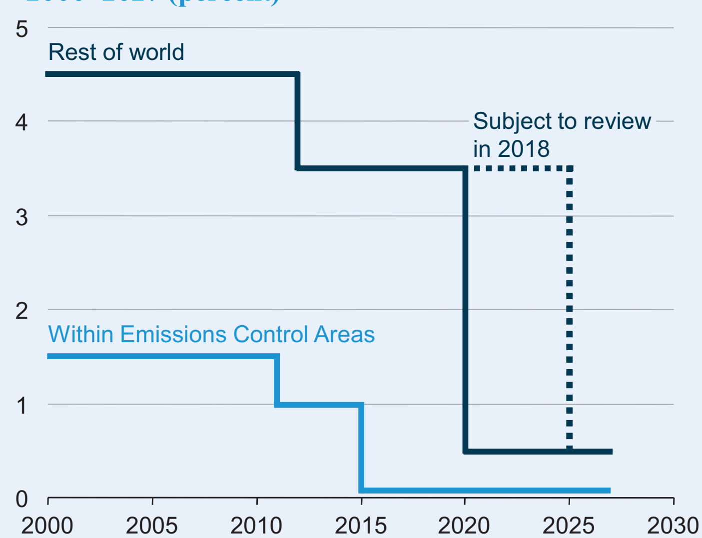



**Figure 2-6. Current and proposed Marpol regulations on sulfur content of residual fuel oil, 2000–2027 (percent)**




[27]International Maritime Organization, "International Convention for the Prevention of Pollution from Ships (MARPOL)" (London, UK: 2015), http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.

[28]When the revised Marpol Annex VI entered into force in July 2010, it included a change to the name and definition of an emission control area from SECA to ECA—an area where special mandatory measures are required to control nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM), or all three types of emissions from ships. See U.S. Environmental Protection Agency, "MARPOL Annex VI" (Washington, DC: September 1, 2015), https://www.epa.gov/enforcement/marpol-annex-vi.

OECD demand for liquid fuels does not grow over the projection period, as the mature economies react to sustained high fuel prices over the long term with strong efficiency gains (especially in personal transportation) and conservation. Although technology efficiency improvements and fuel-switching opportunities also are available to non-OECD consumers, the scale of growth in demand for transportation services in relatively underdeveloped transportation networks overwhelms the mitigating impact of those efficiency improvements.

### *OECD*

For most of the OECD countries, consumption of petroleum and other liquid fuels remains flat or declines in the IEO2016 Reference case (see Figure 2-7). At 46 million b/d in 2040, total OECD liquid fuels consumption is only 0.6 million b/d higher than in 2012. In much of the OECD, slow economic growth and static or declining population levels contribute to lower levels of liquids consumption. In addition, many OECD governments have adopted policies that mandate improvements in the efficiency of motor vehicles, and consumers turn to more fuel-efficient transportation choices as high oil prices return in the long term. Efficiency gains could also lower freight-related energy demand. The U.S. Environmental Protection Agency recently proposed a significant increase in fuel economy standards for heavy trucks. Should these proposed standards be adopted as final rules, they would significantly lower projections for diesel fuel use in trucks. To the extent that these standards are implemented and affect trucks sold throughout the world, the reduction in trucking fuel use could be greatly magnified.

The United States is currently the OECD's largest consumer of liquid fuels, and it remains so through 2040. The use of liquid fuels in the U.S. transportation sector declines over the projection period as a result of significantly lower energy use by light-duty vehicles. However, the decline is moderated by increased energy use for heavy-duty vehicles, aircraft, and marine vessels. Over the course of the projection period, increases in vehicle fuel economy offset growth in transportation activity. Industrial sector demand

**Figure 2-7. OECD and non-OECD petroleum and other liquid fuels consumption, IEO2016 Reference case, 1990–2040 (million barrels per day)**

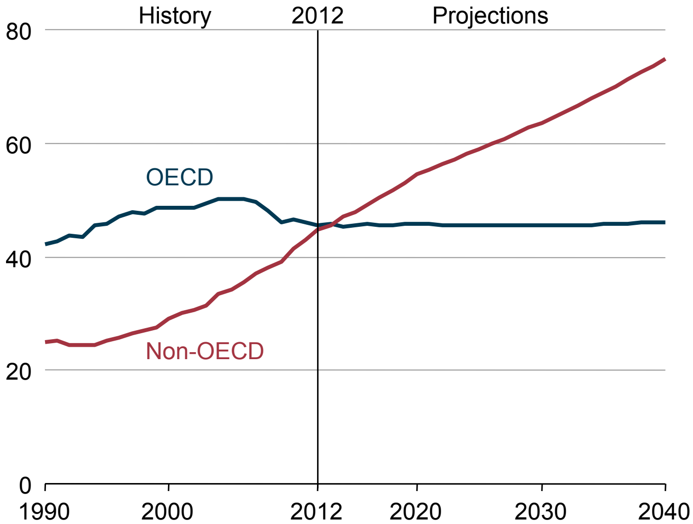



**Figure 2-8. Non-OECD petroleum and other liquid fuels consumption by region, IEO2016 Reference case, 1990–2040 (million barrels per day)**

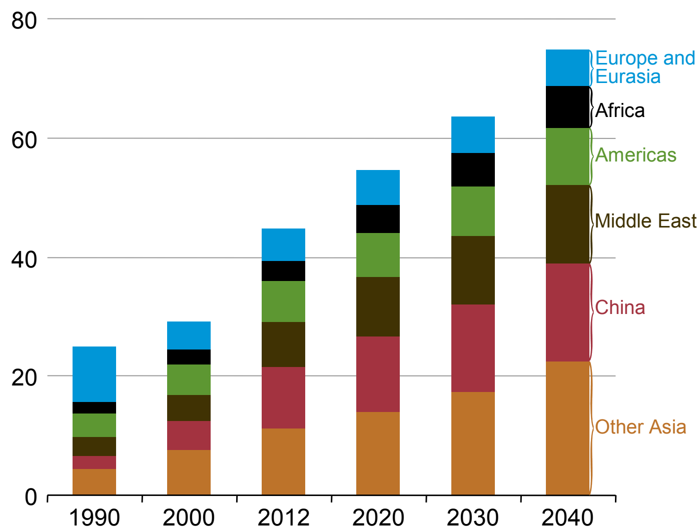



**Table 2-2. World petroleum and other liquid fuels consumption by region, IEO2016 Reference case, 1990–2040 (million barrels per day)**

| | | | | | | | Average annual percent change | |
|---|---|---|---|---|---|---|---|---|
| Region | 1990 | 2000 | 2012 | 2020 | 2030 | 2040 | 1990-2012 | 2012-2040 |
| **OECD** | **42.2** | **48.7** | **45.5** | **45.8** | **45.5** | **46.1** | **0.3** | **0.0** |
| Americas | 20.6 | 24.3 | 23.2 | 24.4 | 24.3 | 24.6 | 0.5 | 0.2 |
| Europe | 14.0 | 15.6 | 14.1 | 13.7 | 13.7 | 14.0 | 0.0 | 0.0 |
| Asia | 7.6 | 8.8 | 8.2 | 7.7 | 7.5 | 7.5 | 0.4 | -0.3 |
| **Non-OECD** | **25.0** | **29.0** | **44.8** | **54.5** | **63.6** | **74.8** | **2.7** | **1.9** |
| Europe and Eurasia | 9.3 | 4.4 | 5.3 | 5.8 | 6.2 | 6.1 | -2.5 | 0.5 |
| Asia | 6.6 | 12.5 | 21.5 | 26.7 | 32.2 | 38.9 | 5.5 | 2.1 |
| Middle East | 3.3 | 4.5 | 7.7 | 10.0 | 11.3 | 13.2 | 3.9 | 2.0 |
| Africa | 2.1 | 2.5 | 3.6 | 4.5 | 5.5 | 6.9 | 2.6 | 2.4 |
| Americas | 3.8 | 5.0 | 6.7 | 7.5 | 8.5 | 9.6 | 2.7 | 1.3 |
| Total world | **67.2** | **77.7** | **90.3** | **100.3** | **109.1** | **120.9** | **1.4** | **1.0** |

for liquid fuels in the United States grows over the projection period, mainly because of increased use of hydrocarbon gas liquids (HGL)—primarily ethane and propane—as feedstocks in the bulk chemicals industry. Total liquid fuels consumption in the United States rises from 18.5 million b/d in 2012 to 19.7 million b/d in the early 2020s, then declines to 19.3 million b/d in 2040.

In Canada, fuel efficiency gains result in relatively flat consumption of petroleum and other liquid fuels, between 2.4 million b/d and 2.5 million b/d throughout the projection period. In Mexico and Chile combined, liquid fuels consumption increases by 0.6%/year—the highest growth rate among the OECD regions except for Australia and New Zealand. Despite improvements in vehicle fuel efficiency, the use of liquid fuels increases in Mexico and Chile, particularly for transportation services (as the infrastructure is still relatively underdeveloped) and for industrial production as demand grows.

In OECD Europe, consumption of liquid fuels remains stable, largely as a result of improvements in energy efficiency. In addition to improvements in motor vehicle fuel efficiency, most of the nations in OECD Europe have high taxes on motor fuels, well-established public transportation systems, and declining or slowly growing populations, all of which slow the growth of transportation energy use. In 2040, liquid fuels consumption in OECD Europe totals 14.0 million b/d, or 0.1 million b/d lower than the 2012 level of 14.1 million b/d.

Petroleum and other liquid fuels consumption in OECD Asia generally declines over the long term, from 8.2 million b/d in 2012 to 7.5 million b/d in 2040. Over the past few years, the region's liquid fuels consumption rose, largely because of increased fuel use in Japan's electric power sector after the March 2011 earthquake and tsunami that severely damaged nuclear reactors at Fukushima Daiichi and subsequently led to the shutdown of all the country's nuclear power reactors by May 2012. To compensate for the loss of nuclear generation, Japan turned, in part, to oil-fired generation to meet demand for electricity in the short term. Consumption of petroleum and other liquid fuels for power generation increased by an estimated 20% from 2011 to 2012 but has fallen as some nuclear capacity has returned to operation, and as renewable generating capacity has grown. With Japan's use of liquid fuels for power generation returning to more typical levels, the country's overall trend of decreasing consumption of petroleum and other liquid fuels resumes in the medium term.

Outside of Japan, the other countries of OECD Asia—South Korea, Australia, and New Zealand—experience some growth in liquids fuels use, attributed mostly to expanding activity in the transportation and industrial sectors. In Australia and New Zealand, expected population growth rates also contribute to a rise in demand for liquid fuels. Together, the two countries are projected to account for the largest increase in demand among the OECD countries in the IEO2016 Reference case.

### *Non-OECD*

The non-OECD share of world liquid fuels consumption grows from 50% in 2012 to 54% in 2020 and to 62% in 2040. Non-OECD Asia shows the largest growth in liquid fuels consumption worldwide in the IEO2016 Reference case, at 17.4 million b/d from 2012 to 2040, with China accounting for 6.2 million b/d of the total increase. As China's economy moves from dependence on energy-intensive industrial manufacturing to services, the transportation sector becomes the most significant source of growth in liquid fuels use. The country's liquid fuels consumption increases by 61% over the course of the projection period.

India's GDP increases by 5.5%/year from 2012 to 2040 in the IEO2016 Reference case—the highest economic growth rate among all the IEO regions. In recent years, India's government has committed to a number of economic and structural reforms that will support the strong projected growth in GDP over the medium to long term. On the other hand, the government's continued efforts to reduce subsidies on petroleum products are expected to temper demand for liquid fuels. In the IEO2016 Reference case, consumption of petroleum and other liquid fuels in India more than doubles, from 3.6 million b/d in 2012 to 8.3 million b/d in 2040, as its GDP more than quadruples over the period.

## Industrial CO2 emissions and petroleum coke use in refineries

EIA has identified possible discrepancies in the international reporting of data on fuels consumed in the petroleum refining sector that may result in underestimation of energy-related emissions of greenhouse gases (GHG). Petroleum refining is one of the world's most energy-intensive industries, and as demand for petroleum products in non-OECD countries continues to grow, their refining industries are adding capacity to process more crude oil into gasoline, diesel, and other petroleum-based products. Evolving crude oil inputs, changing market demands, and increasingly stringent emissions regulations all affect the refining process. As an energy-intensive industry, petroleum refining also is a significant source of GHG emissions, and understanding and tracking the industry's fuel use is essential to understanding its contribution to global GHG emissions.

Energy consumption by refineries includes both purchased fuels and internally derived fuels drawn from the crude oil refining process itself. Petroleum coke (petcoke) is a refinery product that takes the form of a solid, carbon-rich substance resembling coal. There are two kinds of petcoke: catalyst and marketable. Most refineries worldwide produce both types of petcoke, with differences in production levels resulting from different refinery configurations and crude oil inputs. Heavier crudes typically yield higher petroleum coke production.

Catalyst petcoke, or catcoke, is a byproduct from refinery fluid catalytic cracking (FCC) units. Catcoke is burned off the catalyst matrix (generally, pellets or finer sand-sized particles) to maintain catalytic activity, providing energy for FCC processes. Catcoke

*(continued on page 26)*

cannot be collected and sold. Rather, it must be burned onsite as refinery fuel. Catcoke is a significant source of carbon dioxide (CO2) emissions. Marketable petcoke, on the other hand, is produced in coker units. Petcoke is collected and processed in sizable chunks by the refinery and marketed for various uses, such as fuel for cement kilns and power generators. Marketable petcoke also is widely used for nonfuel purposes, especially for conversion to carbon anodes used in aluminum production. When either type is burned, sizable amounts of CO2 are released, along with sulfur and volatile heavy metals. In some countries, including the United States, air quality regulations have made the burning of marketable petcoke prohibitively expensive. As a result, there has been an increase in U.S. exports of marketable petcoke, with more than 14% of the 2012 total delivered to China.[29]

The International Energy Agency (IEA) historical database, among other compilations, provides data on the world supply of marketable petcoke, including production, trade, and consumption data for most nations. Many countries appear to omit catcoke consumption, possibly because it is not sold as a marketed fuel. For those that do report catcoke consumption, there often is no distinction between marketable petcoke and catcoke in the IEA database. However, it appears that most OECD nations (Chile, Mexico, and Poland are a few of the exceptions) provide data for consumption of both marketable and catalyst petcoke in the refining sector, the latter likely representing most petroleum coke consumption.

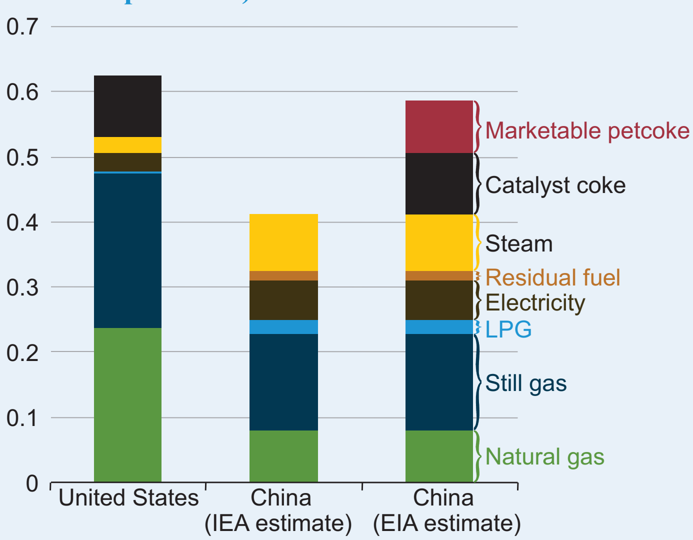
Other nations (including China, Russia, Brazil, and most of the other non-OECD nations) provide data for their petroleum coke supply but not for their refining sector consumption. All of these countries have some FCC units in their refineries, and it is possible that the catalyst coke portion of total petroleum coke consumption is not reported because it is burned in domestic refineries. This situation would cause CO2 emissions for some countries to be underestimated.

China is one country that does not report data on refinery consumption of petcoke. One possible way to estimate its consumption may be to assume that refining operations in the United States and China are not significantly different. If so, one would expect the American and Chinese systems to use about the same amount of energy per barrel of crude oil processed. Total U.S. production of petroleum catcoke (which is equal to refinery consumption of petcoke) is reported to be in the range of 200,000 b/d to 250,000 b/d, equivalent to about 0.1 million Btu of catcoke per barrel of crude processed in U.S. refineries. This value, multiplied by China's crude oil inputs, could provide a first-order approximation of catcoke consumption in China's refineries.

China's production and consumption of catcoke appear to be missing in official state statistics. According to IEA data, there is no reported refinery consumption of either petroleum coke type in China's refineries, which seems unlikely in view of its substantial FCC capacity. Moreover, if the missing refinery fuel is catcoke, and if the United States and China produce roughly the same amount of catcoke per barrel in their FCC units, the unreported catcoke alone is not enough to balance the production equations. Consistent with a recent report on the petcoke market in China,[30] it seems likely that some of China's refineries are using their own marketable petcoke for refinery fuel rather than selling it to outside buyers. Based on recent estimates of China's total marketable petcoke consumption (30 million metric tons in 2012) and the likely fraction of that total employed for fuel and power purposes, it is estimated that 0.08 million Btu per barrel of refinery fuel use in China is marketable petcoke (Figure 2-9).

If the consumption of catcoke and marketable petcoke is not included in the estimation of energy consumption at China's refineries, then GHG emissions from China's refining sector would be underestimated. Based on the analysis summarized here, EIA has incorporated its estimates of marketable petcoke consumed as refinery fuel in the IEO2016 baseline estimates of China's industrial sector energy consumption. Further, China may not be the only example of a country whose consumption of catcoke or petroleum coke goes unreported. Better estimates of refinery consumption of catcoke and petroleum coke fuel, not only for China but elsewhere as well, would enable construction of a more accurate baseline for world industrial sector CO2 emissions in the future.

**Figure 2-9. Energy consumption in U.S. and China refineries by fuel type, 2012 (million Btu per barrel of crude oil produced)**




Notes: Based on Carnegie Endowment data, EIA estimates that 90% (8.8 million metric tons) of China's fuel marketable petcoke is used as fuel in refineries, and the remaining fuel marketable petcoke (1.2 million metric tons) is used as fuel in small electric power plants. A small amount of coal was reported to have been used in U.S. refineries in 2012 and none in China's refineries.

[29] U.S. Energy Information Administration, "Petroleum & other liquids: data: exports by destination: petroleum coke" (October 30, 2015), http://www.eia.gov/dnav/pet/PET_MOVE_EXPC_A_EPPC_EEX_MBBL_A.htm.

[30] Wang Tao, "Managing China's Petcoke Problem" (Beijing, China: Carnegie-Tsinghua Center for Global Policy, May 31, 2015), http://carnegietsinghua.org/2015/06/03/managing-china-s-petcoke-problem/i9fa.

Liquid fuels demand in the Middle East grows substantially in the IEO2016 Reference case, by 5.5 million b/d from 2012 to 2040, as a result of strong population growth rates and rising incomes. In addition, liquids-intensive processes in the region's industrial sector, particularly in the chemicals industry, are an important component of its growing demand for liquid fuels. Delays in petroleum subsidy reforms in much of the region and strong growth in per capita incomes support a significant expansion of liquid fuels consumption in the region's transportation sector. Some subsidy reforms are assumed to occur in the later years of the projection, with the resulting higher prices slowing the region's growth in demand for liquid fuels.

Demand for liquid fuels in the Middle East region's electric power sector declines from 2012 to 2040 in the IEO2016 Reference case. Many of the countries in the region that produce liquid fuels increasingly turn to lower-cost natural gas and, to a lesser extent, nuclear and renewable fuels to increase the volumes of petroleum available for export and to meet demand for fuel in the transportation and industrial sectors. The timing of the Middle East shift from its reliance on liquid fuels for power generation remains uncertain, however, as the region faces delays in infrastructure improvements, and because there are limits on the supply of alternative fuels for power generation. For instance, Saudi Arabia has been unable to meet rapid growth in electricity demand with power generated from domestic natural gas and has had to import fuel oil for power generation.

As in the Middle East, growing populations and economies in African countries increase the demand for liquid fuels for both transportation and industrial uses over the IEO2016 projection. In the IEO2016 Reference case, Africa's consumption of petroleum and other liquid fuels grows by 3.3 million b/d from 2012 to 2040, as its real GDP increases by 4.7%/year from 2012 to 2040. With an expected favorable investment environment and relative political stability in the long term, growing consumer demand is projected to increase demand for consumer goods and services and to increase demand for liquid fuels, particularly for personal transportation and freight services. The transportation sector accounts for 60% of the total increase in liquid fuels use in Africa in the IEO2016 Reference case.

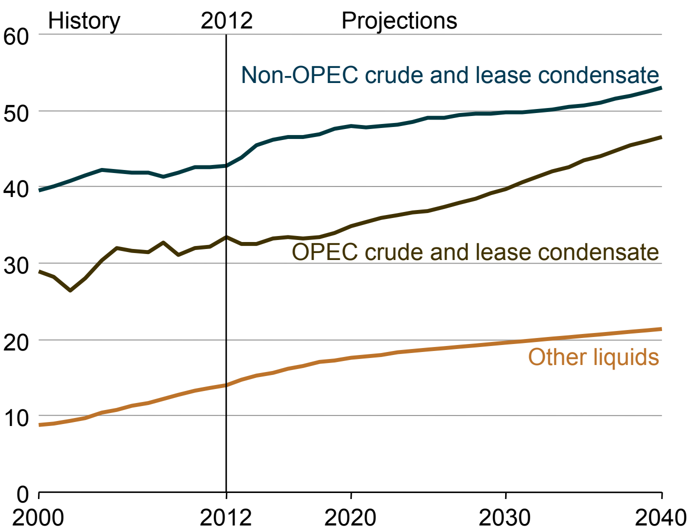
In Brazil and the other non-OECD Americas, consumption of liquid fuels increases by 2.9 million b/d, from 6.7 million b/d in 2012 to 9.6 million b/d in 2040. In some of the region's national economies—notably Brazil, Colombia, and Peru—long-term economic expansion is expected to support growing demand for liquid fuels, primarily for transportation uses but also in the industrial sector. Brazil, with the region's largest economy, accounts for about 60% of the regional growth in liquid fuels demand in the IEO2016 Reference case. Economies that are less financially secure, including Venezuela and Argentina, will have a more difficult time sustaining economic growth. Fuel subsidies in Venezuela, in particular, are costly, and it is difficult to anticipate when the Venezuelan government might be able to reduce the subsidies.

In the countries of non-OECD Europe and Eurasia, demand for liquid fuels grows moderately from 2012 to 2020 in the IEO2016 Reference case before reaching a plateau. Russia—the largest economy in the region—currently accounts for the largest share of the region's consumption of liquid fuels, but as a result of major efficiency improvements in its energy-intensive industrial sector its consumption increases more slowly than in the region's other economies. In addition, demand for liquid fuels in Russia's residential and commercial sectors is projected to slow as fuel subsidies for people living in areas with high heating requirements are reduced.

### *World petroleum and other liquid fuels supplies*

In the IEO2016 Reference case, world petroleum and other liquid fuels supplies depend on various sources, including OPEC and non-OPEC crude oil and lease condensate supply as well as other liquids supply. Crude oil and lease condensate includes tight oil, extra-heavy oil, field condensate, and bitumen (i.e., oil sands, either diluted or upgraded); other liquids supply refers to NGPL, biofuels, CTL, GTL, kerogen, and refinery gain.

**Figure 2-10. Petroleum and other liquid fuels production by region and type in the IEO2016 Reference case, 2000–2040 (million barrels per day)**




### *OPEC crude oil and lease condensate supply*

The IEO2016 Reference case assumes that OPEC maintains or increases its market share of global oil production, and that no geopolitical circumstances will cause prolonged supply shocks in the OPEC countries that could further limit production growth. Crude oil and lease condensate supplies from OPEC and non-OPEC sources increase by 23 million b/d in the IEO2016 Reference case, from 76 million b/d in 2012 to 100 million b/d in 2040. OPEC member countries account for 13 million b/d, and non-OPEC countries account for 10 million b/d of the total increase in crude oil and lease condensate production. Production of other liquid fuels increases from 14 million b/d in 2012 to 21 million b/d in 2040.

The IEO2016 Reference case assumes that OPEC producers invest in incremental production capacity, which enables them to increase crude oil and lease condensate production by 13 million b/d from 2012 to 2040 (Figure 2-10) and also enables them to account for 42% to 47% of total crude and lease condensate production worldwide over the course of the projection period. Middle East OPEC member countries, which accounted for nearly 70% of total OPEC crude and lease condensate production in 2012 (Figure 2-11), increase their crude and lease condensate production by 12 million b/d in the IEO2016 Reference case, accounting for 94% of the total growth in OPEC crude and lease condensate production from 2012 to 2040.

### *Non-OPEC crude and lease condensate supply*

In the IEO2016 Reference case, non-OPEC production of crude oil and lease condensate increases steadily, from 43 million b/d in 2012 to 48 million b/d in 2020 and 53 million b/d in 2040. The average cost per barrel of non-OPEC oil production rises as production volumes increase, and those cost increases, along with falling investment in exploration and production, eventually slow production growth in the IEO2016 Reference case.

U.S. tight oil production, which reached 4.6 million b/d in May 2015 and is estimated to have declined to 4.3 million b/d in February 2016 has proven more resilient in the face of low prices than many market watchers initially anticipated. However, tight oil makes up only a small portion of total non-OPEC supply of crude and lease condensate, which was estimated at roughly 45 million b/d in the first quarter of 2016. Given the long investment cycle for many projects outside of shale plays, the current decline in investment can have long-term effects. Delays and cancelations of planned projects are expected to continue for the next several years, especially for projects with high development costs, such as Canadian oil sands and large offshore projects. Some existing production capacity has also begun coming offline in 2015 as well. For example, a number of fields in the North Sea have been closed earlier than originally planned. Resources with the highest operating costs and most strained financing are expected to be the first to come offline. These resources include tight oil, stripper wells, and fields that experience equipment failures—all of which require ongoing capital investments to offset declines in production from existing wells.

### *Other liquids supply*

Other liquid fuels—including NGPL, biofuels, CTL, GTL, kerogen (oil shale), and refinery gain—currently supply a relatively small portion of total world petroleum and other liquid fuels, accounting for about 16% of the total in 2012. Other liquid fuels are projected to grow modestly in importance in the IEO2016 Reference case, as the other liquids share of the world's total liquids supply increases to 18% in 2040 (see Figure 2-10).

NGPL is the largest component of other liquids, accounting for 67% of the total in 2012 (Figure 2-12). The increase in NGPL production in IEO2016 is directly related to the increase in natural gas production, of which NGPL is often a coproduct. In contrast, increased production of other liquids (primarily biofuels, CTL, and GTL) occurs in response to high prices that support expansion of their production with available domestic resources, such as crops, coal, or gas. In the IEO2016 Reference case, sustained low oil prices in the early years of the projection make the development of the non-NGPL other liquids less economically attractive. In addition to being price-sensitive, biofuels development also relies heavily on policies or mandates to support growth.

**Figure 2-11. OPEC crude and lease condensate production by region in the IEO2016 Reference case, 2012, 2020, and 2040 (million barrels per day)**

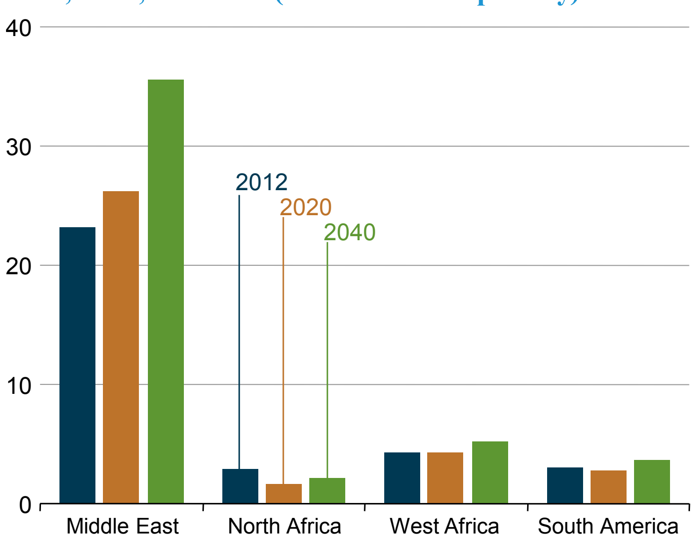
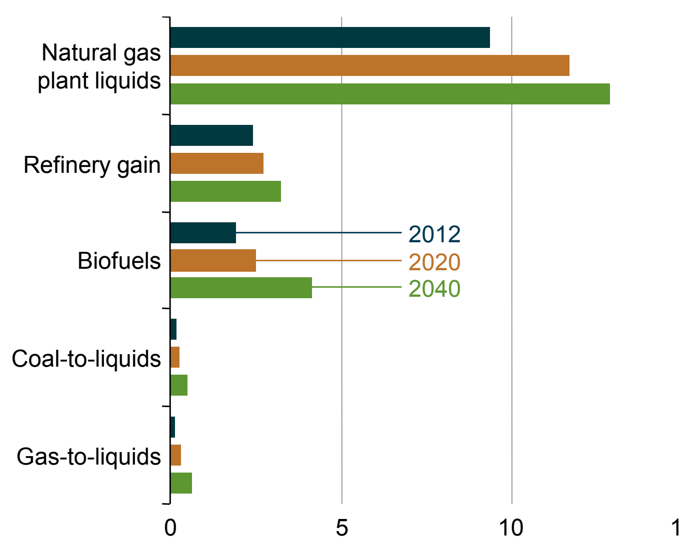



**Figure 2-12. World other liquid fuels production by source, 2012, 2020, and 2040 (million barrels per day)**



## Iran's return to the international oil market

Implementation Day for the Joint Comprehensive Plan of Action (JCPOA) agreement among Iran, the P5+1 (the five permanent members of the United Nations Security Council and Germany), and the European Union (EU), occurred on January 16, 2016, when the International Atomic Energy Agency verified that Iran had completed the key physical steps required to trigger sanctions relief. With this milestone, the United States, the EU, and the United Nations lifted nuclear-related sanctions against Iran, which included oil-related sanctions that limited Iran's ability to sell its oil on the global market since late 2011. With nuclear-related sanctions being lifted:

- Some Iranian banks can rejoin the Society for Worldwide Interbank Financial Telecommunication (SWIFT) system to conduct financial transactions electronically on the world market.
- Iran can access its foreign cash reserves held in banks worldwide. According to the U.S. Department of Treasury, Iran's Central Bank has between $100 billion and $125 billion in foreign exchange assets globally, but its usable liquid assets are estimated at slightly more than $50 billion.
- Non-U.S. companies can invest in Iran's oil and natural gas industry, including the sale, supply, and transfer of equipment and technology.
- Countries within the EU and elsewhere can import oil, natural gas, and petrochemical products from Iran, and countries already importing from Iran can increase their purchases.
- European Protection and Indemnity (P&I) Clubs can provide insurance and reinsurance for Iranian oil tankers.

Previously imposed U.S. primary sanctions related to human rights abuses and terrorism remain in place, and some Iranian citizens and entities that were delisted under nuclear sanctions as a result of the JCPOA agreement will remain listed under these primary sanctions. In addition, the United States has imposed new sanctions on individuals and entities linked to recent ballistic missile tests by Iran.[31] As a result, non-U.S. companies may be slow to rush back into Iran until they determine how they can resume business without violating the prevailing sanctions. U.S. companies remain precluded from conducting business with Iran, with the exception of foreign subsidiaries of U.S. firms that receive case-by-case approvals from the U.S. Department of the Treasury.

Although its crude oil exports were nearly halved by sanctions between 2011 and 2014, Iran still ranks among the world's top 10 producers of oil and among the top 5 producers of natural gas. Iran's crude oil production has been relatively flat over the past three years, averaging 2.8 million barrels per day (b/d) and representing 9% of OPEC's total crude oil production.[32] Iran' s total liquids production in 2015 amounted to nearly 3.5 million b/d, and its total production of dry natural gas in 2013 was estimated at 5.7 trillion cubic feet.[33] Iran is the world's fourth-largest holder of oil reserves (nearly 158 billion barrels) and the world's second-largest holder of natural gas reserves (1.2 trillion cubic feet).[34]

The pace at which Iran will ramp up its exports now that sanctions have been lifted is uncertain. Iran has a considerable amount of oil stored offshore in tankers (between 30 million and 50 million barrels, most of which is condensate) and at onshore facilities. Initial post-sanction increases in Iran's exports are likely to come from storage, with meaningful production increases occurring after some of the storage has been cleared. Most of the production growth is expected to come from crude oil production capacity that currently is shut in, and the remainder is expected to come from newly developed fields. Iranian and Chinese companies have been developing a number of new oil fields in Iran over the past several years, which have the potential to add 100,000 b/d to 200,000 b/d of crude oil production capacity by 2017.

In addition to crude oil, Iran's current production of condensate and NGPL totals nearly 750,000 b/d, of which 75% is condensate and the remainder NGPL. Iran's noncrude liquids production has grown over the past few years, with its main buyers in Asia (mainly China) and the United Arab Emirates (UAE). Currently, there is an oversupply of condensate on the global market as a result of increased production from Australia, the United States, and the Middle East. Iran has had difficulty selling the condensate it produces both because of the oversupply and because of its high sulfur content. As a result, the condensate has been sold at a discount.[35] Iran's production of other liquids is expected to grow by 150,000 b/d by the end of 2016 and by an additional 100,000 b/d by the end of 2017, as more project phases at the South Pars natural gas field come online.

Iran has the potential to add almost 2 million b/d of crude oil, condensate, and natural gas plant liquids to the global market over the next five years. However, the global oil market already is oversupplied, and EIA projects that oil inventories will continue to

*(continued on page 30)*

[31]U.S. Department of the Treasury, "Treasury Sanctions Those Involved in Ballistic Missile Procurement for Iran" (January 17, 2016), https://www.treasury.gov/press-center/press-releases/Pages/jl0322.aspx.

[32]U.S. Energy Information Administration, "Iran's petroleum production seen rising as many sanctions are lifted," *This Week in Petroleum* (January 21, 2016), https://www.eia.gov/petroleum/weekly/archive/2016/160121/includes/analysis_print.cfm.

[33]U.S. Energy Information Administration, "Under sanctions, Iran's crude oil exports have nearly halved in three years," *Today in Energy* (June 24, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=21792.

[34]U.S. Energy Information Administration, "Iran," *Country Analysis Brief* (June 19, 2015), http://www.eia.gov/beta/international/analysis.cfm?iso=IRN.

[35]U.S. Energy Information Administration, "Nuclear accord creates potential for additional crude oil production from Iran," *Today in Energy* (August 13, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=22492.

build throughout 2016.[36] Consequently, Iran's ability to increase its crude oil sales may be limited by global demand and the availability of buyers.

Actual production growth after 2017 will depend on Iran's ability to attract foreign investment that will provide access to better technology, a higher level of expertise, and more financing opportunities. Iran recently modified its contract structure in hopes of increasing joint development of its oil and natural gas fields by both international and Iranian oil companies. Iran's restrictive buyback contracts will be replaced by a new Iran Petroleum Contract (IPC), which was formally introduced in Tehran, Iran, in November 2015 (although the final draft of the IPC has not been released). Notable changes include allowing foreign companies to book reserves in Iran in some cases (although they will not be permitted to own fields[37]) and increasing contract durations to as much as 25 years (which will allow IOCs to participate beyond exploration and development and into the production and secondary recovery phases). Under the IPC, fees and bonuses will be based on a project's associated risks. At the Tehran conference in November 2015, Iran unveiled a list of 53 oil and natural gas projects, along with 18 exploration blocks, which it hopes will attract at least $30 billion in foreign investment.[38]

There are notable risks associated with Iran's production outlook. The JCPOA includes a dispute resolution process and guidance for the *snap back* of sanctions if Iran strays from its commitments. As a result, there is a possibility that sanctions could be reinstated, which adds a downside risk to Iran's production outlook. In addition, the involvement of the Iranian Revolutionary Guard Corps (IRGC) in Iran's oil and natural gas industry complicates the outlook for foreign investment. The IRGC, which is subject to U.S. sanctions related to sponsorship of international terrorism, maintains ownership interests in many of Iran's service sector companies, presenting a potential problem for foreign companies that want to use Iranian contractors.

## Foreign investment in Algeria's hydrocarbon development

Algeria is currently the third-largest oil producer (after Nigeria and Angola) in Africa and is also the continent's largest natural gas producer. Over the past decade, however, Algeria's production of both oil (Figure 2-13) and natural gas (Figure 2-14) has declined, leading the Algerian government to amend its law on foreign investment in hydrocarbons in an attempt to attract the investment and technology improvements needed to help stop production declines. In 2014, after the Algerian Council of Ministers gave formal approval for foreign partners to join the national oil and natural gas company, Sonatrach, in exploring and developing shale gas resources, Sonatrach offered 33 blocks in four sedimentary basins with high shale gas and oil potential to foreign bidders. Following the auction, the company signed five contracts with Repsol, Shell, Statoil, and Dragon Oil-Enel. By law, Sonatrach takes a majority share (at least 51%) of any resulting projects.

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**Figure 2-13. Crude oil production in Algeria, 2005-14 (thousand barrels per day)**

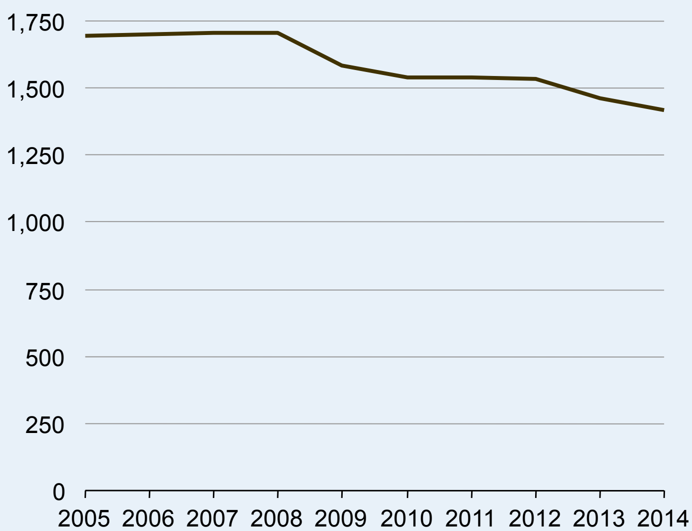
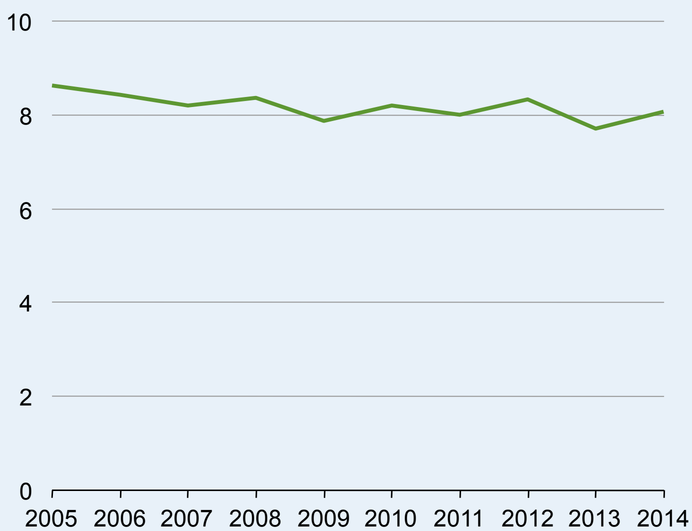



**Figure 2-14. Natural gas production in Algeria, 2005-14 (billion cubic feet per day)**



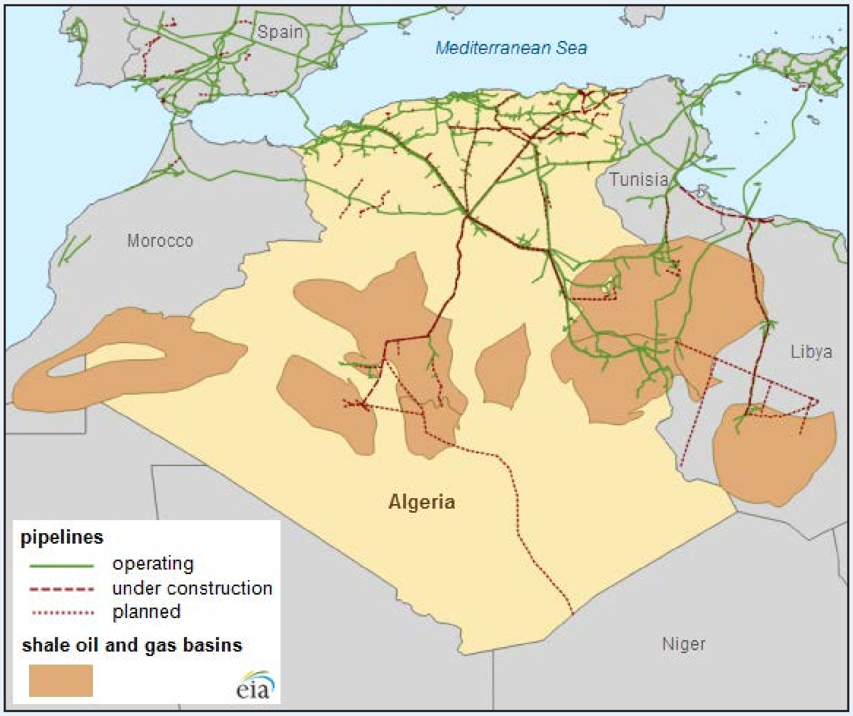

[36]U.S. Energy Information Administration, "Global Petroleum and Other Liquids," *Short-Term Energy Outlook* (January 12, 2016), https://www.eia.gov/forecasts/steo/report/global_oil.cfm.

[37]Although companies can book reserves, the National Iranian Oil Company (NIOC) retains exclusive ownership of fields.

[38]A. Lidgett, "Iran's New Oil And Gas Contract Framework Revealed," *International Business Times* (November 28, 2015), http://www.ibtimes.com/irans-new-oil-gas-contract-framework-revealed-2202878.

Algeria has large proved reserves of crude oil and natural gas, as well as resources that already are connected to world markets through an extensive natural gas pipeline network (Figure 2-15). In addition, Algeria's large shipping fleet transports liquefied natural gas (LNG) from several liquefaction plants to customers in Europe and elsewhere. Proved crude oil reserves in Algeria totaled 12.2 billion barrels in 2014. In addition, the U.S. Geological Survey (USGS) has estimated the country's undiscovered oil and NGL resources at 9.8 billion barrels, while EIA and Advanced Resources International (EIA/ARI) have estimated close to 6 billion barrels of technically recoverable shale oil resources. Proved natural gas reserves totaled 159 trillion cubic feet (Tcf) in 2014, with an additional 49 Tcf of undiscovered natural gas resources estimated by USGS and more than 700 Tcf of technically recoverable shale gas resources estimated by EIA/ARI.

**Figure 2-15. Oil and natural gas basins and pipeline infrastructure in Algeria**




Early this year, Sonatrach announced plans to spend $64 billion, or 70% of its total investment program from 2015 to 2018, in upstream activities to reverse the decline in crude oil and natural gas production in Algeria. Sonatrach set a target to increase gross hydrocarbon output from 1,429 million barrels of oil equivalent (MMBOE) in 2014 to 1,649 MMBOE by 2019 (from 535 MMBOE to 616 MMBOE of oil and from 894 to 1,034 MMBOE of natural gas).

Over the past three years, Sonatrach has intensified its exploration activities, drilling 275 oil and natural gas wells and seismically mapping large areas of the country with an estimated investment of $30 billion, and has conducted its own shale resource assessment and started exploration activities. The first two vertical shale exploratory wells drilled by Sonatrach in 2012 confirmed the potential for shale gas, and since 2014 Sonatrach has been engaged in a pilot project in the shale gas-rich Ahnet basin to drill, hydraulically fracture, and analyze three horizontal wells with up to 14 hydraulic fracturing stages.

While the government is seeking to reduce Algeria's dependence on oil and natural gas revenue, it has also made repeated calls for more investment in the sector. However, civil unrest and some opposition to the government's commercialization of shale resources may present obstacles to attracting foreign investment. Security is also a major concern, particularly following the attacks that took place at the Tigantourine natural gas processing plant in Illizi Province, near Algeria's eastern border with Libya, in January 2013.

## Update on Mexico's petroleum sector reforms

In December 2013, Mexico took the first step toward reforming its energy sector by amending its constitution to open the sector to external investment. Since then, the Mexican parliament has passed secondary laws and instituted a regulatory framework to manage the newly restructured sector. The secondary laws passed in 2014 included the Hydrocarbons Law, which created institutional frameworks for the oil sector, along with a process for auctioning contracts; the Hydrocarbons Revenue Law, which established fiscal, legal, and regulatory regimes for the auctioned contracts; and subsidiary regulations on implementation, published in October 2014. The Comisión Nacional de Hidrocarburos (CNH, or Hydrocarbons Commission), which was established to implement the reforms, began conducting bid rounds in 2015 to auction rights for the exploration and development of Mexico's oil resources.

The petroleum sector reforms are intended to encourage foreign investment to help reverse recent declines in Mexico's oil production and to develop a healthy and diverse exploration and production (E&P) industry. The main objective of the process was to maximize hydrocarbon-related revenue to the state, rather than the number of contract blocks awarded.[39] However, the price of oil has fallen by nearly 65% since June 2014, and E&P spending has declined globally as companies seek to cover revenue shortfalls.[40] Concerns about regulatory, contract, or administrative structure on the part of companies or their investors are amplified in the present environment of low oil prices, and investment has fallen precipitously in new projects that will not result in demonstrable production for several years.

The bid round process (Table 2-3) began in August 2014 with Round Zero, in which Petróleos Mexicanos (Pemex) received the right of first refusal (before bidding was opened to other entities) on hydrocarbon resources that could be developed quickly. Pemex retained rights to explore and develop 83% of Mexico's proved and probable reserves and 21% of its prospective resources, as well as the option to migrate these entitlements to other contract structures.[41]

### Table 2-3. Pemex bid Round One process and timeline as of December 2015

| Process phase | Date | Activity |
|---|---|---|
| | | Round Zero |
| **Pemex entitlements** | August 2014 | • Retained projects it can develop quickly<br>• Awarded 83% of proved and probable (2P) reserves and 21% of prospective resources |
| | | Round One |
| **Phase One**<br>Shallow water exploration | July 2015 | • 2 of 14 blocks awarded<br>• Production-sharing contracts (PSCs) issued, mostly for light oil resources |
| **Phase Two**<br>Shallow water production | September 2015 | • 3 of 5 blocks awarded<br>• PSCs issued |
| **Phase Three**<br>Onshore production | December 2015 | • 25 blocks awarded, most to Mexican E&P companies<br>• License contracts (LCs) to be issued |
| **Phase Four**<br>Deepwater exploration and extra-heavy oil production | Third quarter 2016 (probable) | • 10 deepwater blocks in the Gulf of Mexico and 11 blocks of extra-heavy oil to be auctioned and awarded[a]<br>• Tax and royalty regime to be used for deepwater projects |
| **Phase Five**<br>Chicontopec Basin / tight oil | To be determined | • 61 blocks in unconventional fields, including 12 blocks in the Chicontopec field,[b] to be auctioned and awarded<br>• May be delayed to next round |

[a]IHS Energy, "Mexico: Lessons learned from early auctions drive new approaches for deepwater," *Oil and Gas Risk Service* (November 20, 2015), https://connect.ihs.com/Document/Show/gi/2852236?connectPath=Search (subscription site).
[b]C. Pascual, IHS Energy, "Mexico's energy reforms: strategic challenges ahead," *CERA Special Report* (August 2015), https://connect.ihs.com/Document/Show/gi/2823645?connectPath=Search (subscription site).

Bidding was opened to other entities in Round One, which began with an auction of shallow-water exploration blocks in July 2015 (Phase One). In response to industry feedback on the terms of the first auction, CNH made changes for the second auction in September 2015 (Phase Two, shallow-water production blocks) that resulted in considerably more industry interest. To participate in the first two phases, companies and consortia were required to meet technical and financial criteria and thresholds. (The different

*(continued on page 33)*

[39]"Mexico's first bid round proves a disappointment," *Petroleum Intelligence Weekly* (July 20, 2015), http://www.energyintel.com/pages/login.aspx?fid=art&DocId=893018 (subscription site).
[40]U.S. Energy Information Administration, "Sustained low oil prices could reduce exploration and production investment," *This Week in Petroleum* (September 23, 2015), http://www.eia.gov/petroleum/weekly/archive/2015/150923/includes/analysis_print.cfm.
[41]Pemex, "Newsletter No. 3: Round Zero Resolution & Round One Updates" (September 2014), http://www.ri.pemex.com/files/content/No.%203%20Round%200%20&%20Round%201.pdf.

phases of a single bid round also are referred to as tenders.) The criteria included minimum previous or current E&P experience (barrels produced, capital investments in E&P activities, and, in the case of a consortium operator, a net worth of at least $1 billion). Participating entities bid on two criteria: government share of operating profit, and incremental investment over the minimum work program commitment. The government's weighting ratio served to balance its two objectives: maximizing state revenues in the short term, and at the same time ensuring the long-term development of a healthy Mexican E&P sector.[42]

In December 2015, the third phase of Round One awarded rights to produce from onshore fields. Because it was intended to attract more participation by Mexican firms, CNH relaxed expertise criteria for companies to qualify as operators. It began allowing companies without previous E&P experience to qualify by showing evidence that members of their staff have prior experience with E&P projects.[43]

The fourth phase of Round One will include deepwater blocks in the Gulf of Mexico (GOM). With massive petroleum resources and proximity to existing infrastructure on the U.S. side of the GOM, this phase is attracting the most attention from international oil companies (IOCs). However, deepwater projects have long lead times and are technically challenging. Recognizing that the risks are more acute in a low price environment, CNH is adjusting the structure of contract terms to attract the most interest from IOCs. Contract blocks are being reshuffled and consolidated in response to complaints that offerings were too small.

The fifth phase, which may be postponed to a future bid round, will focus on the Chicontopec Basin and other tight oil resources. In a low oil price environment, however, there is less incentive to undertake new E&P ventures, especially challenging ones such as deepwater or tight oil.

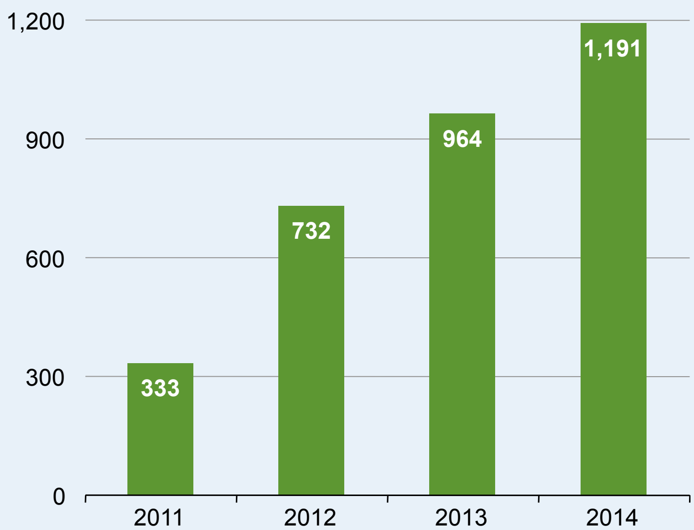
Throughout the process, Mexico's energy agencies—CNH and the energy ministry, Secretaría de Energía (SENER)—have sought input and feedback and have incorporated the feedback into the terms for subsequent phases. For example, in response to industry feedback from a relatively unsuccessful first phase, contract terms were amended to be more in line with international standards.[44]

EIA expects that CNH and the other agencies involved in the process will continue to learn from experience, adapt, and improve to garner increased interest and revenue in later phases. The process continues to be dynamic, although it is directed toward achieving Mexico's stated main objective of maximizing revenue to the state by increasing production in the next several years.

## New biofuels from hydroprocessed esters and fatty acids

A new type of renewable diesel fuel is produced in response to biofuel mandates and customer demand for higher quality. Unlike other biofuels, hydroprocessed esters and fatty acids (HEFA) are nearly indistinguishable from their petroleum counterparts.[45] Worldwide, more than a billion gallons of HEFA fuels were produced in 2014 (Figure 2-16).

**Figure 2-16. World production of renewable diesel fuels from hydroprocessed esters and fatty acids, 2011–14 (million gallons)**




HEFA fuels are hydrocarbons rather than alcohols or esters. During the refining process, oxygen is removed from the esters and fatty acids that make up vegetable oil, leaving only hydrocarbons. Hydrocarbons from nonpetroleum sources are known as drop-in fuels, because they are nearly identical to comparable petroleum-based fuels. HEFA fuels, which are the most common drop-in biofuels, can be used in diesel engines without blending with petroleum diesel fuel. Currently, HEFA fuels are approved by ASTM International for use in jet engines, at blend rates up to 50% with petroleum jet fuel.[46]

To date, the HEFA biofuel most commonly produced has been a diesel replacement fuel that is marketed abroad as hydrotreated vegetable oil (HVO) and in the United States as renewable diesel. HEFA fuels are produced by reacting vegetable oil or animal fat with hydrogen in the presence of a catalyst. The equipment and process are very similar to the hydrotreaters used to reduce diesel sulfur levels in petroleum refineries. There are currently 10 plants worldwide that

*(continued on page 34)*

[42]F. Tanner et al., "Mexico: Learning from the first phase of Round 1," *Oil and Gas Risk Service* (July 30, 2015), https://www.pfcenergy.com/Members/PRM/Special-Reports-and-Quarterly-Outlooks/2015/Mexico-Learning-from-the-first-phase-of-Round-1 (subscription site).

[43]P.M. Lara, "Mexican E&P companies emerge," *Strategic Horizons* (IHS Energy: October 26, 2015), https://www.pfcenergy.com/Members/Horizons/Exploration-and-Production/2015/Mexican-EP-companies-emerge (subscription site).

[44]Energy Intelligence, "Mexico's flexibility bodes well for first bid round," *Petroleum Intelligence Weekly* (June 29, 2015), http://www.energyintel.com/pages/articlesummary/890602/mexico-s-flexibility-bodes-well-for-first-bid-round (subscription site).

[45]Note: EIA does not collect statistics on international HEFA fuels.

[46]ASTM International, "Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons," ASTM D7566-15c (West Conshohocken, PA: 2015), http://www.astm.org/Standards/D7566.htm.

produce renewable diesel, one of which is ENI's former petroleum refinery in Venice, Italy.[47] Total is planning to convert its La Mede, France, refinery to HVO production,[48] and four additional renewable diesel projects are being developed by other producers. Finnish Neste is the world's largest producer of renewable diesel. Other major producers are Italy's ENI, U.S.-based Diamond Green Diesel, and Swedish refiner Preem.

Beyond diesel, another outlet for HEFA fuels using similar technology is biojet fuel, which can be blended with petroleum jet fuel in proportions up to 50%. As with any alternative jet fuel, HEFA biojet fuel is required to meet stringent specifications to ensure its performance under a wide range of conditions. One potential consumer of HEFA bioject fuel is the U.S. Department of Defense, which intends to use biojet fuel in its JP-8 jet fuel. JP-8 is a versatile fuel used in military vehicles, stationary diesel engines, and jet aircraft.[49] This use of a common fuel simplifies logistics. There is also civilian interest in nonpetroleum jet fuel: Alaska Airlines, KLM, and United Airlines have demonstrated the use of HEFA biojet fuel on commercial flights since 2011.

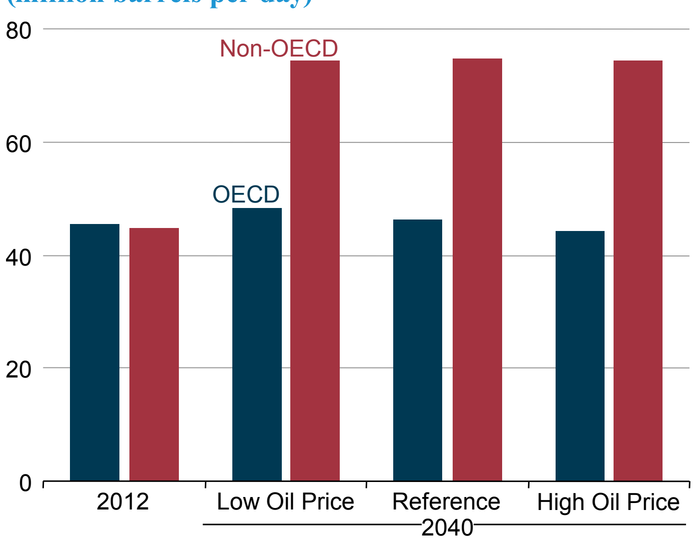
## Low Oil Price case

Across the three IEO2016 price cases, OPEC's crude and lease condensate production falls as oil prices rise from the Low Oil Price case to the High Oil Price case. Alternatively, non-OPEC production of both petroleum and other liquid fuels increases as oil prices increase from the Low Oil Price case to the High Oil Price case.

In the IEO2016 Low Oil Price case, crude oil prices are $76/b in 2040. GDP growth in the non-OECD countries averages 3.9%/year from 2012 to 2040, compared with 4.2%/year in the IEO2016 Reference case. The combination of lower economic activity and lower prices results in non-OECD liquid fuel consumption in 2040 that is very close to that in the IEO2016 Reference case (Figure 2-17). Even in a scenario where low economic growth translates to lower energy demand (non-OECD energy demand in 2040 is 26 quadrillion Btu lower than in the IEO2016 Reference case), the lower prices encourage consumers to use cheap liquid fuels rather than other forms of energy. In contrast, economic growth in the OECD regions is essentially the same in the Low Oil Price case as in the IEO2016 Reference case. Total OECD energy consumption in 2040 is about the same as in the IEO2016 Reference case, but lower prices encourage consumers to use more liquid fuels compared to other energy sources. As a result, in 2040 OECD nations consume 48 million b/d of oil in the Low Oil Price case, compared with 46 million b/d in the IEO2016 Reference case.

On the supply side, OPEC's market share of world crude and lease condensate production ranges between 42% and 45% through 2020, then rises to 53% in 2040, as its production increases from 33 million b/d in 2012 to 54 million b/d in 2040, and its share of total world liquid fuels production in 2040 is 44%. In contrast, because North Sea Brent prices are lower than in the IEO2016 Reference case, non-OPEC crude and lease condensate production increases by only about 6 million b/d, to 48 million b/d in 2040, or 5 million b/d lower than in the IEO2016 Reference case. With higher average costs for resource development in the non-OPEC countries, the North Sea Brent crude oil price in the Low Oil Price case is not sufficient to make many undeveloped fields economically viable. Production of other liquid fuels, which typically are more expensive to produce, also grows more slowly than in the IEO2016 Reference case. In the Low Oil Price case, total production of other liquid fuels increases from 14 million b/d in 2012 to 20 million b/d in 2040, or 1.5 million b/d lower than in the IEO2016 Reference case (Figure 2-18).

**Figure 2-17. World petroleum liquid fuels consumption in three cases, 2012 and 2040 (million barrels per day)**




## High Oil Price case

World oil prices in the High Oil Price reach $149/b in 2020 and $252/b in 2040, and higher assumed costs for crude and lease condensate production result in lower production than in the IEO2016 Reference case. Lower crude and lease condensate supply results in higher prices, which incentivize increased development of liquid supplies from price-sensitive emerging sources, including tight oil, bitumen, and other liquid fuels, which have higher production costs.

GDP growth in the non-OECD countries averages 4.5%/year from 2012 to 2040 in the High Oil Price case, as compared with 4.2%/year in the IEO2016 Reference case. The combination of high economic activity and high prices results in non-OECD liquids consumption that is about the same as in the IEO2016 Reference case (see Figure 2-17). Although the higher level

[47]Eni S.p.A., "Green Refinery" (October 11, 2014), http://www.eni.com/en_IT/innovation-technology/technological-focus/green-refinery/green-refinery.shtml.

[48]R. Kotrba, "A Transformative Project: Total's La Mède Conversion," *Biodiesel Magazine* (November 20, 2015), http://www.biodieselmagazine.com/articles/606885/a-transformative-project-totals-la-mede-conversion.

[49]Shell Global, "Military Jet Fuel Grades and Specifications (NATO)," http://www.shell.com/global/products-services/solutions-for-businesses/aviation/shell-aviation-fuels/fuels/types/military-jet-fuel-grades.html.

of economic activity increases non-OECD demand for total energy (total non-OECD energy consumption in 2040 is about 27 quadrillion Btu higher in the High Oil Price case than in the IEO2016 Reference case), the higher costs associated with liquid fuels encourages consumers to use other energy sources. On the other hand, the greater economic activity boosts incomes, making fuels more affordable for consumers.

OECD economic growth in the High Oil Price case is unchanged from the IEO2016 Reference case, and total energy demand is similar in the two cases. Higher oil prices in combination with the same IEO2016 Reference case economic activity mean that OECD consumers implement improved efficiency and conservation measures and switch to less expensive fuels where possible. In 2040, the OECD region as a whole consumes 44 million b/d in the High Oil Price case, or 2.0 million b/d less than in the IEO2016 Reference case.

On the supply side, liquid fuels production in the OPEC countries is lower in the High Oil Price case than in the IEO2016 Reference case, and their market share of total petroleum and other liquid fuels production declines to between 34% and 39%. Non-OPEC crude and lease condensate production increases initially in the High Oil Price case at about the same rate as in the IEO2016 Reference case. In the medium term, access to resources is lower than in the Reference case and non-OPEC production is not able to grow beyond Reference case levels, despite the higher prices. In the long term, however, high world oil prices induce more non-OPEC supply into the market. In the High Oil Price case, non-OPEC crude and lease condensate production increases to 58 million b/d in 2040, or 5 million b/d higher than in the IEO2016 Reference case (see Figure 2-18).

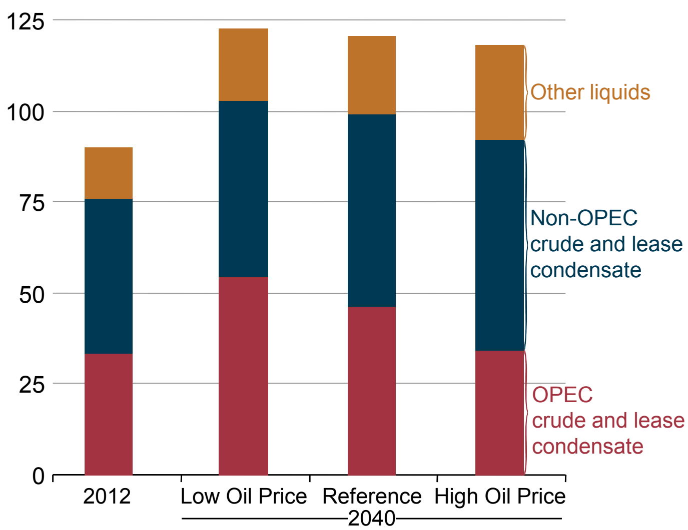
Liquid fuels production in the OPEC countries is lower in the High Oil Price case than in the IEO2016 Reference case, and their share of total petroleum and other liquid fuels production declines over the projection. As a result, the OPEC market share of world petroleum and other liquids production in the High Oil Price case never exceeds the peak of 42% that it reached in 2008 and eventually declines to 34% in 2040. OPEC petroleum and other liquids production increases by only 3 million b/d, from 37 million b/d in 2012 to 40 million b/d in 2040 (as compared with an increase of nearly 15 million b/d in the IEO2016 Reference case).

The economics of other liquid fuels also benefit from higher prices in the High Oil Price case. Non-OPEC production of other liquid fuels increases to 20 million b/d in 2040, nearly 5 million b/d higher than in the IEO2016 Reference case; and Non-OPEC production of NGPL grows to 10 million b/d in 2040, 2 million b/d higher than in the IEO2016 Reference case. Higher oil prices also lead to significant increases in non-OPEC production of biofuels, CTL, and GTL as compared with the IEO2016 Reference case. In 2040, non-OPEC other liquids supplies (excluding NGPL) are 2 million b/d higher in the High Oil Price case than in the IEO2016 Reference case.

## Reserves

Proved reserves of crude oil are the estimated quantities that geological and engineering data indicate can be recovered in future years from known reservoirs, assuming existing technology and current economic and operating conditions. Most increases in proved reserves since 2000 have come from revisions to reserves in discovered fields, rather than new discoveries.[50] As of December 2015, proved world oil reserves, as reported by the *Oil & Gas Journal*, were estimated at 1,656 billion barrels—2 billion barrels higher than the estimate at the end of 2014.[51] According to the *Oil & Gas Journal*, around half of the world's proved oil reserves are located in the Middle East, and more than 80% of the world's proved reserves are concentrated in eight countries,[52] of which only Canada (with oil sands included) and Russia are not members of OPEC. In 2013, the largest increase in proved reserves by far was attributed to Venezuela, as the country now reports its Orinoco belt extra-heavy oil in its totals.[53] As a result, Venezuela's reserves alone increased by 86 billion barrels from 2012 to 2013. Russia also reported a significant gain in 2013, at 20 billion barrels. Country-level estimates of proved reserves from the *Oil & Gas Journal* are developed from data reported to the U.S. Securities and Exchange Commission (SEC), from foreign government reports, and from international geologic assessments. The estimates are not always updated annually.

**Figure 2-18. World petroleum and other liquid fuels production in three cases, 2012 and 2040 (million barrels per day)**




[50]International Energy Agency, *World Energy Outlook 2012* (Paris, France: November 12, 2012), http://www.worldenergyoutlook.org/weo2012/.

[51]C. Xu, T. Dunnahoe, M.T. Slocum, and L. Bell, "Reserves grow modestly as crude oil production climbs," *Oil & Gas Journal* (December 7, 2015), http://www.ogj.com/articles/print/volume-113/issue-12/special-report-worldwide-report/reserves-grow-modestly-as-crude-oil-production-climbs.html (subscription site).

[52]Canada, Iran, Iraq, Kuwait, Russia, Saudi Arabia, United Arab Emirates, and Venezuela.

[53]"Global oil production up in 2012 as reserve estimates rise again," *Oil & Gas Journal* (December 3, 2012), http://www.ogj.com (subscription site).

In some cases in the IEO2016 projections, country-level volumes for cumulative production through 2040 exceed the estimates of proved reserves. This does not imply that resources and the physical limits of production have not been considered in the development of production forecasts, or that the projections assume a rapid decline in production immediately after the end of the projection period as reserves are depleted. EIA considers resource availability in all long-term country-level projections, the aggregation of which gives the total world production projection. However, proved reserves are not an appropriate measure for judging total resource availability in the long run. For example, despite continued production, global reserves historically have not declined, because new reserves have been added through exploration, discovery, and reserve replacement.

Proved reserves are only a subset of the entire potential oil resource base. Resource base estimates include estimated quantities of both discovered and undiscovered liquids that have the potential to be classified as reserves at some time in the future. The resource base may include oil that currently is not technically recoverable but could become recoverable in the future as technologies advance. In the IEO2016 Reference case, the resource base does not pose a global constraint on oil supply.

To construct plausible projections for petroleum liquids production, underlying analysis must consider both production beyond the end of the projection period and the physical realities and limitations of production. Proved reserves cannot provide an accurate assessment of the physical limits on future production but rather are intended to provide insight as to company-level or country-level development plans in the near term. Because of the particularly rigid requirements for the classification of resources as proved reserves, even the cumulative production levels from individual development projects may exceed initial estimates of proved reserves.

EIA attempts to address the lack of applicability of proved reserves estimates to long-term production projections by developing a production methodology based on the true physical limits of production, initially-in-place volumes, and technologically limited recovery factors. By basing long-term production assessments on resources rather than reserves, EIA is able to present projections that are physically achievable and can be supported beyond the 2040 projection horizon. The realization of such production levels depends on future growth in world demand, taking into consideration such aboveground limitations on production as profitability and specific national regulations, among others.

Chapter 3

# Natural gas

## Overview

Consumption of natural gas worldwide is projected to increase from 120 trillion cubic feet (Tcf) in 2012 to 203 Tcf in 2040 in the *International Energy Outlook 2016* (IEO2016) Reference case. By energy source, natural gas accounts for the largest increase in world primary energy consumption. Abundant natural gas resources and robust production contribute to the strong competitive position of natural gas among other resources. Natural gas remains a key fuel in the electric power sector and in the industrial sector. In the power sector, natural gas is an attractive choice for new generating plants because of its fuel efficiency. Natural gas also burns cleaner than coal or petroleum products, and as more governments begin implementing national or regional plans to reduce carbon dioxide (CO2) emissions, they may encourage the use of natural gas to displace more carbon-intensive coal and liquid fuels.

World consumption of natural gas for industrial uses increases by an average of 1.7%/year, and natural gas consumption in the electric power sector increases by 2.2%/year, from 2012 to 2040 in the IEO2016 Reference case. The industrial and electric power sectors together account for 73% of the total increase in world natural gas consumption, and they account for about 74% of total natural gas consumption through 2040.

Consumption of natural gas increases in every IEO region, with demand in nations outside the Organization for Economic Cooperation and Development (non-OECD) increasing more than twice as fast as in the OECD (Figure 3-1). The strongest growth in natural gas consumption is projected for the countries of non-OECD Asia, where economic growth leads to increased demand. Natural gas consumption in the non-OECD region grows by an average of 2.5%/year from 2012 to 2040, compared with 1.1%/year in the OECD countries. As a result, non-OECD countries account for 76% of the total world increment in natural gas consumption, and their share of world natural gas use grows from 52% in 2012 to 62% in 2040.

To meet the rising natural gas demand projected in the IEO2016 Reference case, the world's natural gas producers increase supplies by nearly 69% from 2012 to 2040. The largest increases in natural gas production from 2012 to 2040 occur in non-OECD Asia (18.7 Tcf), the Middle East (16.6 Tcf), and the OECD Americas (15.5 Tcf) (Figure 3-2). In China alone, production increases by 15.0 Tcf as the country expands development of its shale resources. The United States and Russia increase natural gas production by 11.3 Tcf and by 10.0 Tcf, respectively. In Russia, production growth is supported primarily by increasing development of resources in the country's Arctic and eastern regions. U.S. production growth comes mainly from shale resources. Total natural gas production in China, the United States, and Russia accounts for nearly 44% of the overall increase in world natural gas production.

Although there is more to learn about the extent of the world's tight gas, shale gas, and coalbed methane resource base, the IEO2016 Reference case projects a substantial increase in those supplies—especially in China, the United States, and Canada (Figure 3-3). The application of horizontal drilling and hydraulic fracturing technologies has made it possible to develop the U.S. shale gas resource, contributing to a near doubling of estimates for total U.S. technically recoverable natural gas resources over the past decade. Shale gas accounts for more than half of U.S. natural gas production in the IEO2016 Reference case, and tight gas, shale gas, and coalbed methane resources in Canada and China account for about 80% of total production in 2040 in those countries.

Liquefied natural gas (LNG) accounts for a growing share of world natural gas trade in the Reference case. World LNG trade more than doubles, from about 12 Tcf in 2012 to 29 Tcf in 2040. Most of the increase in liquefaction capacity occurs in Australia and North America, where a multitude of new liquefaction projects are planned or under construction, many of which will become

**Figure 3-1. World natural gas consumption, 2012–40 (trillion cubic feet)**

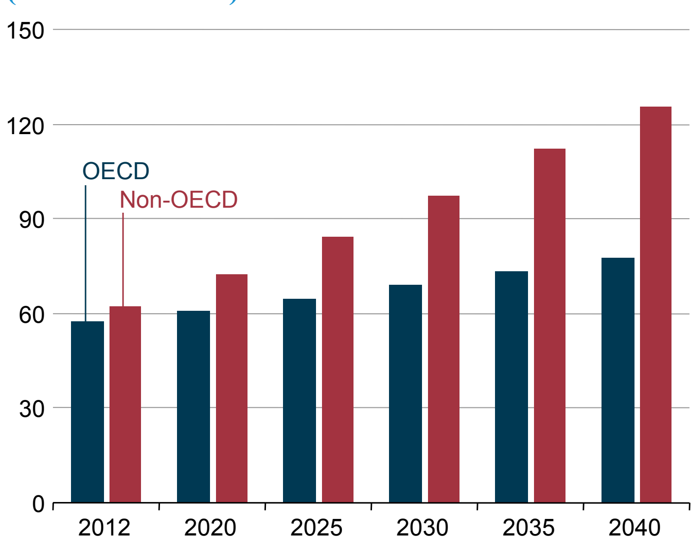
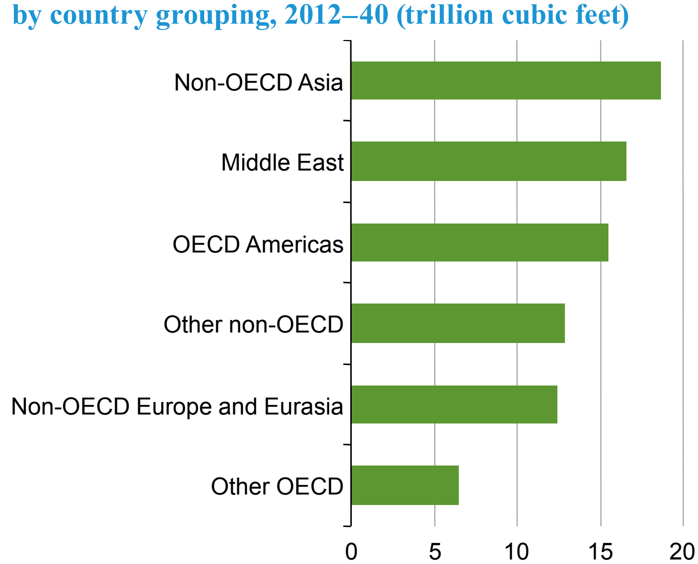



**Figure 3-2. World increase in natural gas production by country grouping, 2012–40 (trillion cubic feet)**



operational within the next decade. At the same time, existing facilities in North Africa and Southeast Asia have been underutilized or are shutting down because of production declines at many of the older fields associated with the liquefaction facilities, and because domestic natural gas consumption is more highly valued than exports.

## OECD natural gas consumption

### *OECD Americas*

Annual natural gas consumption in the OECD Americas region rises steadily to 40.1 Tcf in 2040 (Figure 3-4), including increases of 1.0 Tcf from 2012 to 2020 (0.4%/year) and 7.3 Tcf from 2020 to 2040 (1.0%/year). The OECD Americas region accounts for 41% of the total increase in natural gas use by OECD countries and 13% of the increase in total world natural gas consumption over the projection period.

The United States—the world's largest consumer of natural gas—leads the OECD Americas region in annual natural gas consumption growth with an increase of 4.2 Tcf from 2012 to 2040, or 51% of the region's total increase (Figure 3-5). While the recently finalized Clean Power Plan (CPP) regulations in the United States are not included in the IEO2016 Reference case, its effects are considered in discussions, tables, and figures throughout the report, based on prior U.S. Energy Information Administration (EIA) analysis of the proposed rule that has similar elements. With implementation of the proposed CPP, U.S. natural gas consumption would be 1.7 Tcf higher in 2020 compared to the IEO2016 Reference case. Most of the increase in natural gas consumption would occur in the electric power sector as a substitute for coal-fired generation. After 2020, the effect of the CPP on natural gas use in the power sector decreases as generation from renewable energy increases. In 2040, projected U.S. natural gas consumption is 1.0 Tcf lower with the CPP than in the IEO2016 Reference case. Effects of the final CPP on natural-gas-fired generation will depend on natural gas prices, renewable technology costs, and state-level implementation decisions. An increase in natural gas use through 2040 is certainly possible in scenarios with low gas prices and implementation strategies that favor gas.

Projections for combined annual natural gas consumption in Mexico and Chile include absolute growth in the two countries of 2.2 Tcf (26% of the OECD Americas total increase), followed by Canada with 1.9 Tcf (23% of the OECD Americas total increase). Increasingly, Mexico has met its growing demand for electricity with generation from natural gas-fired units, using natural gas imported by pipeline from the United States, particularly since 2011 as the growth of Mexico's overall natural gas consumption has outstripped its domestic production growth. In the IEO2016 Reference case, the electric power sector accounts for 39% (3.2 Tcf) of the growth in natural gas consumption from 2012 to 2040 in the OECD Americas region, with 1.6 Tcf of the increase occurring in Mexico and Chile and 1.3 Tcf in Canada.

**Figure 3-3. Natural gas production by type in China, Canada, and the United States, 2012 and 2040 (trillion cubic feet)**

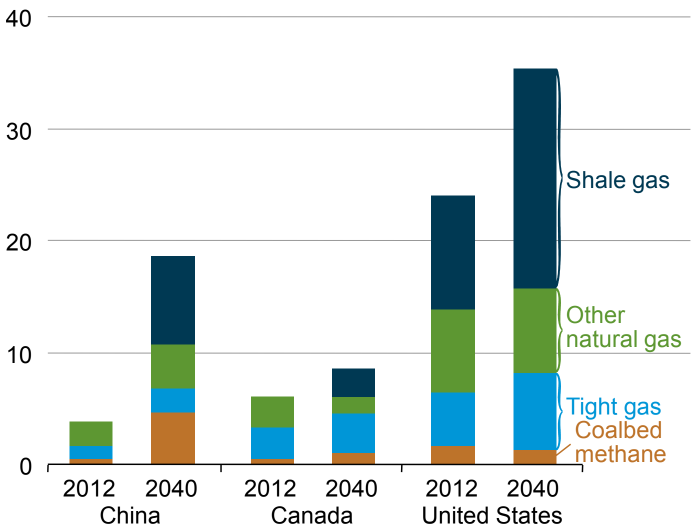



**Figure 3-4. OECD Americas natural gas consumption by country, 2012–40 (trillion cubic feet)**

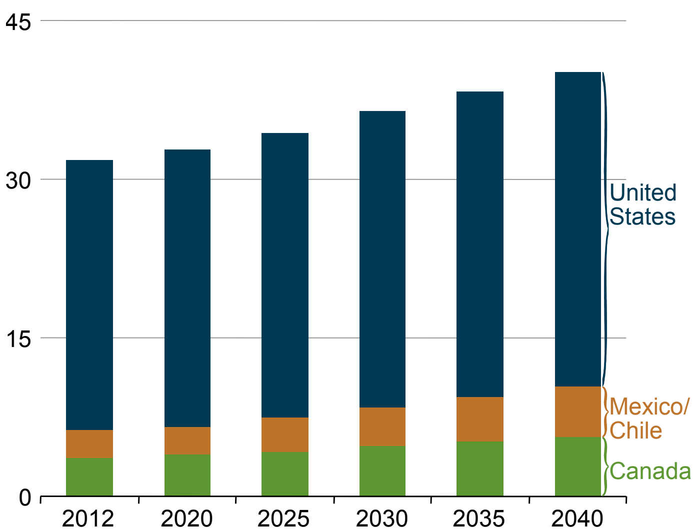
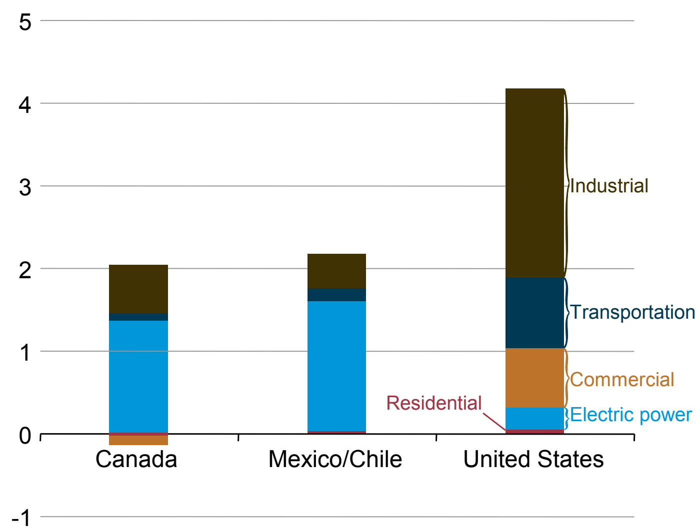



**Figure 3-5. OECD Americas change in natural gas consumption by country and end-use sector, 2012–40 (trillion cubic feet)**



Natural gas use in the OECD Americas industrial sector grows by 1.4 Tcf from 2012 to 2020, with 1.3 Tcf (97%) added in the United States, where industrial consumption increases by an average of 1.8%/year. The growth of natural gas use in the U.S. industrial sector slows somewhat from 2020 to 2040 averaging 0.5%/year and increasing by a total of 1.0 Tcf over that period. In Canada, natural gas consumption in the industrial sector grows by an average of 0.2%/year from 2012 to 2020 and by 1.1%/year from 2020 to 2040. In the Mexico/Chile region, industrial sector natural gas use grows by averages of 0.1%/year from 2010 to 2020 and 1.2%/year from 2020 to 2040.

### OECD Europe

Natural gas consumption in the OECD Europe region grows by 1.3%/year on average, from 17.8 Tcf in 2012 to 25.3 Tcf in 2040 in the Reference case (Figure 3-6), with the electric power sector accounting for more than one-half (4.6 Tcf) of the total increase. The average increase of 3.6%/year in natural gas consumption for power generation from 2020 to 2040 is higher than for any other energy source used in the sector. The share of natural gas in the power generation mix is projected to grow, as older nuclear and coal-fired units will be gradually decommissioned and replaced primarily by new natural gas-fired and renewable capacity.

### OECD Asia

Natural gas consumption in OECD Asia grows by an average of 1.6%/year in the IEO2016 Reference case, from 7.9 Tcf in 2012 to 12.2 Tcf in 2040, with Japan's consumption increasing by an average of 0.9%/year. Japan has relied primarily on short-term and spot cargo shipments of LNG to offset the loss of nuclear generating capacity when a large part of its nuclear generation capacity was shut down after the Fukushima Daiichi power reactors were severely damaged by the March 2011 earthquake and tsunami. All but 2 of the country's 50 reactors remained offline as of January 2016,[54] and environmental concerns have led the government to encourage natural gas consumption, making LNG a fuel of choice for power generation to substitute for the lost nuclear generation. According to the International Gas Union, Japan operated 23 major LNG import terminals in 2014, including expansions and satellite terminals, with the total gas send-out capacity of 9 Tcf/year being well in excess of demand.[55] From 2020 to 2040, Japan's real GDP increases by an average of 0.5%/year, by far the lowest in the region, as a result of its declining population and aging work force. Although Japan's natural gas consumption does not slow between 2020 and 2040, its consumption of energy from liquids and coal does decline. As a result, the natural gas share of Japan's total energy consumption rises from 25% in 2020 to nearly 30% in 2040.

South Korea's natural gas consumption grows at average rates of 2.3%/year from 2012 to 2020 and 1.7%/year from 2020 to 2040 in the IEO2016 Reference case. Growth in demand for natural gas in the South Korea's industrial, residential, and commercial sectors slows, while in the electric power sector it remains above 2%/year throughout the 2012–40 period.

Australia and New Zealand have OECD Asia's strongest average annual growth in electricity sector natural gas consumption from 2012 to 2040 in the IEO2016 Reference case, averaging 4.6%/year and more than tripling, from 0.4 Tcf in 2012 to 1.5 Tcf in 2040 (Figure 3-7). Australia increases the share of natural gas in its power generation mix to reduce its more carbon-intensive coal-fired generation. The two countries' combined share of OECD Asia's total natural gas use for electricity generation grows from 10% in 2012 to 21% in 2040 in the IEO2016 Reference case.

**Figure 3-6. OECD Europe natural gas consumption by end-use sector, 2012–40 (trillion cubic feet)**

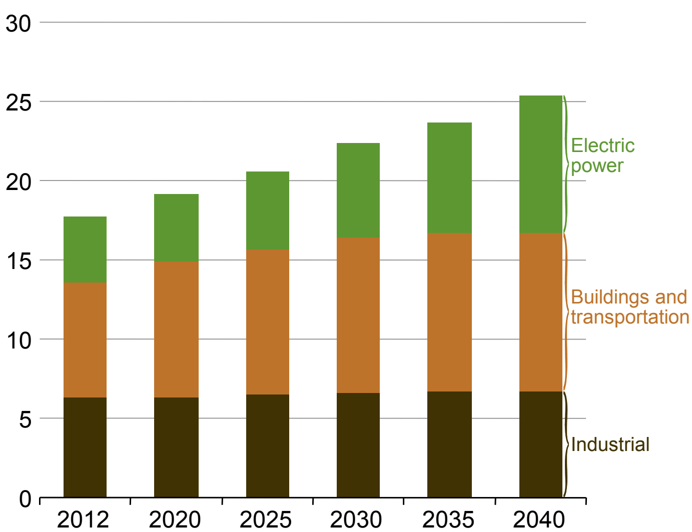
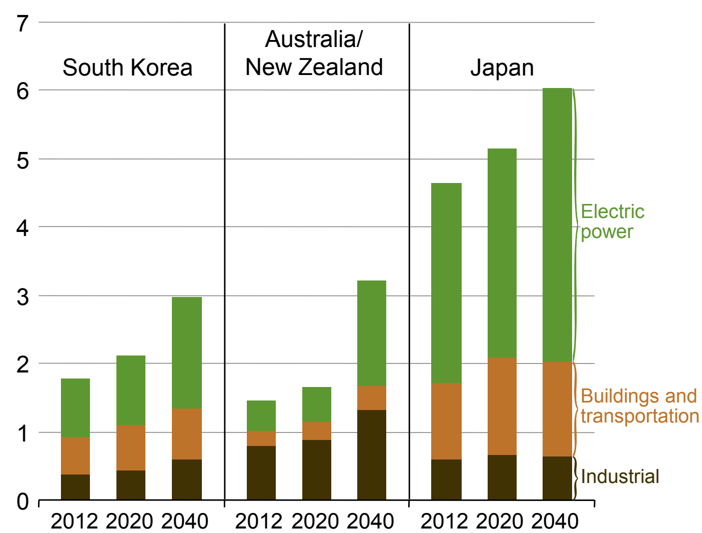



**Figure 3-7. OECD Asia natural gas consumption by country and end-use sector, 2012–40 (trillion cubic feet)**




[54]Nuclear Energy Institute, "Japan Nuclear Update" (Washington, DC: January 26, 2016), http://www.nei.org/News-Media/News/Japan-Nuclear-Update.

[55]International Gas Union, World LNG Report - 2015 Edition (Forenbu, Norway: 2015), pp. 79-81, http://www.igu.org/sites/default/files/node-page-field_file/IGU-World%20LNG%20Report-2015%20Edition.pdf.

## Natural gas prices in Asia

In Asian markets, unlike those in the United States, natural gas prices typically reflect contracts that are indexed to prices for crude oil or petroleum products. The declines in crude oil prices between August 2014 and January 2015 and low oil prices since then (Figure 3-8) had a significant effect on Asian natural gas prices and markets. However, Asian countries are developing regional trading hubs to set natural gas prices that better reflect natural gas market dynamics. In 2014, almost 30% of global trade in LNG occurred on a short-term[56] or spot basis. Asian countries accounted for three-quarters of that total and one-third of the global natural gas trade.[57] From 2011 to 2014, high crude oil prices resulted in higher prices for LNG imports. In Asia, most natural gas is imported as LNG, with LNG prices traditionally indexed to crude oil on a long-term, contractual basis.

Currently there is no globally integrated market for natural gas, and pricing mechanisms vary by regional market. In most cases, internationally traded natural gas is indexed to crude oil prices, such as North Sea Brent or Japan customs-cleared crude (JCC), because of the liquidity and transparency of crude oil prices and the substitutability of natural gas and petroleum products in some markets. For example, some Asian countries have the option to burn either natural gas or petroleum for electricity generation.

Although long-term contracts indexed to crude oil prices remain Asia's predominant pricing mechanism, natural gas is beginning to be traded in one-time transactions on the spot market, or under short-term contracts that more closely reflect international natural gas supply and demand balances. Short-term and spot LNG trade in the Asia Pacific market almost tripled from 2010 to 2014 (Figure 3-9), when it represented 21% of global LNG trade and 7% of natural gas trade.

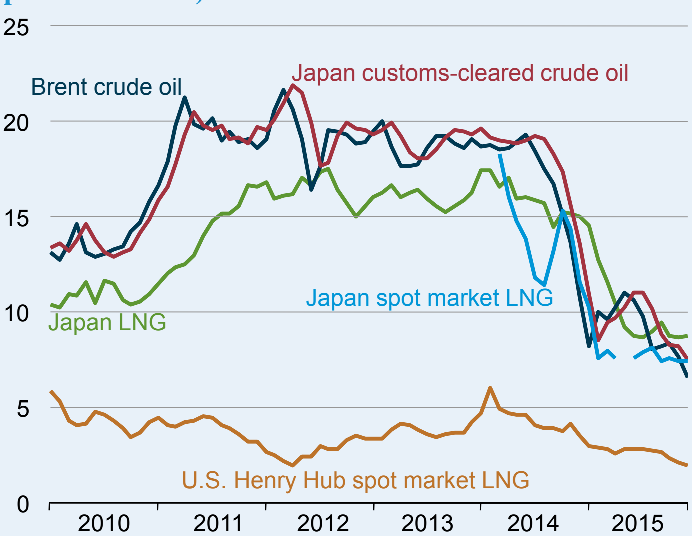
Several Asian countries—including Japan, China, and Singapore—are developing regional trading hubs with the goal of increasing price formation transparency:

- In September 2014, Japan launched an LNG futures contract on the Japan over-the-counter exchange (JOE), settled against the Rim Intelligence Co. Daily Pricing Index. However, only one trade has been made on the JOE since its inception. The country's lack of pipeline connectivity with other markets, low volumes of flexible LNG, and lack of LNG price transparency and liquidity have limited spot LNG trading activity on the JOE.
- In June 2015, Singapore's Stock Exchange launched the Singapore SGX LNG Index Group (SLInG). The index will provide free-on-board prices (excluding shipping costs) for LNG cargos from Singapore to different destinations reflecting regional spot prices. As of June 2015, 13 market players had signed up to participate in the index, and 10 more were expected to join; however, trading volumes to date have been moderate.
- On July 1, 2015, China launched the Shanghai Oil and Gas Exchange, which will trade both pipeline gas and LNG. China's diversified natural gas market, with expanding pipeline infrastructure and gas-on-gas competition, may offer a more liquid Asian natural gas price index, but high levels of government regulation make it less attractive as a regional benchmark.

In Europe, where natural gas is imported both by pipeline and as LNG, natural gas prices are either indexed to crude oil prices or based on the spot market. Although most of trade in Europe is based on long-term contracts, hub-based spot trading has increased

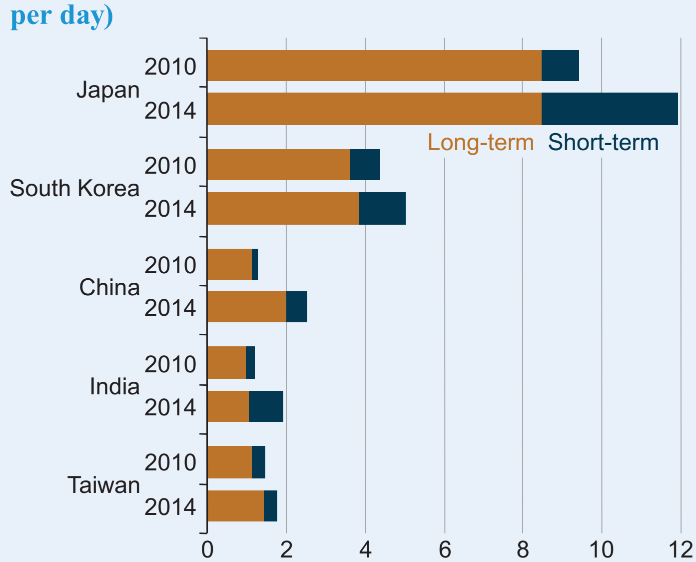
*(continued on page 41)*

**Figure 3-8. World crude oil, natural gas, and liquefied natural gas prices, 2010–15 (nominal dollars per million Btu)**




Note: Japan spot market LNG price for May 2015 was not reported.

**Figure 3-9. Asia Pacific natural gas trade by country and contract type, 2010 and 2014 (billion cubic feet per day)**




[56]Defined here as trade volumes delivered under contracts with duration of 4 years or less.
[57]Includes natural gas trade by pipeline and LNG.

significantly over the past decade. The primary benchmark prices for spot trading are the National Balancing Point (NBP) in the United Kingdom and the Title Transfer Facility (TTF) in the Netherlands. The NBP and TTF prices have a strong influence on hub prices in other European markets because of their liquidity and interconnectivity with continental Europe. Other trading hubs in continental Europe are growing in terms of traded volumes and the numbers of hubs and participants. With the increasing volumes and liquidity in the European hubs, hub pricing is beginning to play a larger role. Some recent pipeline contracts in continental Europe now include a hub-based price, rather than a traditional linkage to a basket of crude oil products.

Prices at Henry Hub, the U.S. natural gas benchmark, can also affect global pricing through LNG trade. By 2020, when all current U.S. liquefaction projects are expected to be completed, the United States will account for almost one-fifth of global liquefaction capacity and will have the third-largest LNG export capacity in the world (after Qatar and Australia).

Almost 80% of U.S. LNG export volumes for projects currently under construction have been contracted on pricing terms directly linked to the Henry Hub price, or under a hybrid pricing mechanism with links to Henry Hub. The flexibility of destination clauses in U.S. LNG export contracts and the introduction of hub indexes are expected to promote greater liquidity in global LNG trading, shift pricing away from oil-based indexes, and contribute to the development of Asian regional trading hubs and pricing indexes.

## Non-OECD natural gas consumption

### *Non-OECD Europe and Eurasia*

The countries of non-OECD Europe and Eurasia relied on natural gas for 47% of their primary energy needs in 2012—the second highest of any country grouping in IEO2016, after the Middle East. Non-OECD Europe and Eurasia consumed a total of 23.0 Tcf of natural gas in 2012, the most outside the OECD and more than any other region in the world except the OECD Americas. Russia's 15.7 Tcf of natural gas consumption in 2012 accounted for 68% of the Non-OECD Europe and Eurasia region's total (Figure 3-10).

In the IEO2016 Reference case, overall natural gas consumption in non-OECD Europe and Eurasia grows by an average of 0.4%/year from 2012 to 2040, including a decline of 0.3%/year from 2012 to 2020 and an increase of 0.7%/year from 2020 to 2040, for a total increase of 2.9 Tcf over the 2012–40 period. With Russia accounting for only about 10% of the region's total increase, the average increase for the rest of the non-OECD Europe and Eurasia region is 1.1%/year, compared with Russia's average of 0.1%/year. In the electric power sector, natural gas consumption falls by an average of 0.1%/year from 2012 to 2040 in Russia as growth in its overall energy use slows but grows by an average of 1.4%/year in the region's other countries.

### *Non-OECD Asia*

Among all regions of the world, the fastest growth in natural gas consumption in the IEO2016 Reference case occurs in non-OECD Asia. Natural gas use in non-OECD Asia increases by an average of 4.4%/year, from 15.1 Tcf in 2012 to 50.8 Tcf in 2040 (Figure 3-11). Over the period, non-OECD Asia accounts for more than 40% of the total incremental growth in world natural gas use, moving from its current position as the world's fourth-largest natural gas consuming region to the second-largest natural gas consuming region in 2030 and the largest consumer in 2040. OECD Asia's total natural gas consumption increases from less than half that of the OECD Americas region in 2012 to more than 25% above the OECD Americas total in 2040, and its share of total world natural gas consumption increases from 13% in 2012 to 25% in 2040.

China accounts for almost two-thirds (63%) of the growth in non-OECD Asia's natural gas consumption from 2012 to 2040. Total consumption of natural gas in China increases by an average of 6.2%/year in the IEO2016 Reference case, from 5.1 Tcf in 2012 to

**Figure 3-10. Non-OECD Europe and Eurasia natural gas consumption, 2012–40 (trillion cubic feet)**

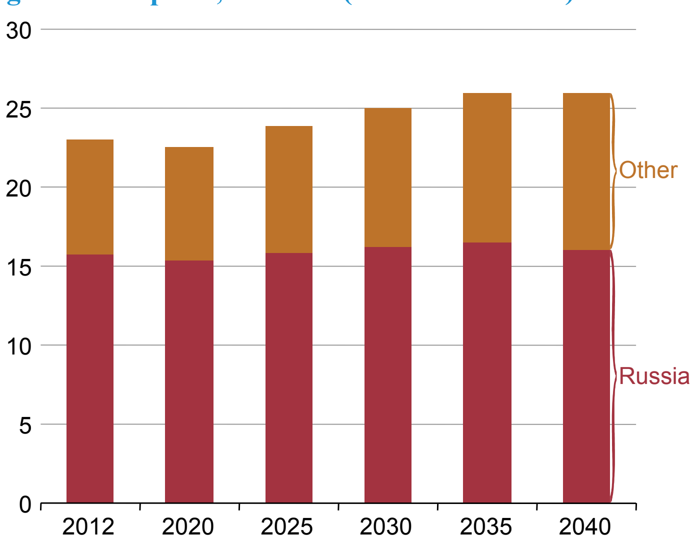
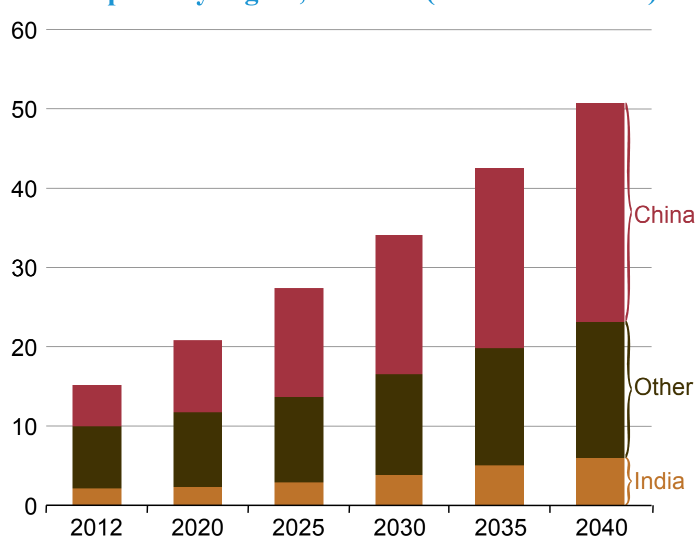



**Figure 3-11. Non-OECD Asia natural gas consumption by region, 2012–40 (trillion cubic feet)**



27.5 Tcf in 2040. China's central government is promoting natural gas as a preferred energy source and has set an ambitious target of increasing the share of natural gas in its overall energy mix to 10% (or approximately 8.8 Tcf) by 2020 to alleviate pollution from its heavy coal use.[58] In the IEO2016 Reference case, natural gas consumption in China totals 9.1 Tcf in 2020, or about 6% of the country's total energy consumption. In 2040, the natural gas share of China's energy consumption is 15%—still less than coal's 44% share. However, the 6.2% average annual growth rate for natural gas consumption from 2012 to 2040 is far below the 9.7% average growth rate for nuclear energy.

In India, natural gas accounted for about 8% of total energy consumption in 2012, almost double the share in China's energy mix. In other countries of non-OECD Asia, natural gas use accounts for 23% of overall energy consumption in 2012, and its share rises to 25% in 2040 in the IEO2016 Reference case, as natural gas consumption increases by an average of 2.8%/year, from 7.9 Tcf in 2012 to 17.2 Tcf in 2040. Although natural gas remains the second-largest source of energy consumption after liquids, its annual growth rate is less than the rates for renewables (3.4%) and nuclear energy (2.9%).

### *Middle East*

In the Middle East region, natural gas accounted for almost half of total energy consumption in 2012, more than in any other region. In the IEO2016 Reference case, Middle East natural gas consumption increases by an average of 2.5%/year from 2012 to 2040, and the industrial sector accounts for the largest share of the region's total natural gas consumption (Figure 3-12). Natural gas use in the industrial sector grows by 7.7 Tcf from 2012 to 2040, accounting for more than half of the 14.2 Tcf total increase in natural gas consumption. In the electric power sector, natural gas use grows by 5.2 Tcf from 2012 to 2040, when it totals 9.8 Tcf. Natural gas-fired generation gains a portion of the market as the use of crude oil for electricity generation declines.

### *Africa*

Africa's natural gas consumption totals 11.1 Tcf in 2040 in the IEO2016 Reference case, or 2.5 times the 2012 total (Figure 3-13). The region's natural gas use increases by an average of 3.3%/year from 2012 to 2040, a rate that is second only to the 4.4%/year average increase for nuclear energy over the same period. Africa's electric power and industrial sectors account for 79% of the increase in the region's demand for natural gas from 2012 to 2040 and for 84% of its total natural gas demand in 2040. Natural gas consumption in the electric power sector grows from 2.2 Tcf in 2012 to 5.5 Tcf in 2040, accounting for 49% of the total increase in Africa's natural gas use over the period. More than 85% of the increase in natural gas use for electricity generation in Africa occurs from 2020 to 2040, when it averages 3.6%/year, as compared with an average of less than 2.5%/year from 2012 to 2020.

### *Non-OECD Americas*

Natural gas consumption in the non-OECD Americas region increases by an average of 2.0%/year in the IEO2016 Reference case, from 5.1 Tcf in 2012 to 8.9 Tcf in 2040 (Figure 3-14). The industrial sector accounts for more than one-third of the consumption growth from 2012 to 2040, followed by the electric power sector at approximately one-quarter. Brazil's natural gas consumption grows by an average of 2.6%/year from 2012 to 2040, or by a total of 1.1 Tcf—more than 25% of the overall increase of 3.9 Tcf for the non-OECD Americas region. The increase from 0.7 Tcf in 2012 to 1.4 Tcf in 2040 in Brazil's industrial sector natural gas consumption accounts for more than 60% of the country's total increase in natural gas use from 2012 to 2040. Consumption of

**Figure 3-12. Middle East natural gas consumption by end-use sector, 2012–40 (trillion cubic feet)**

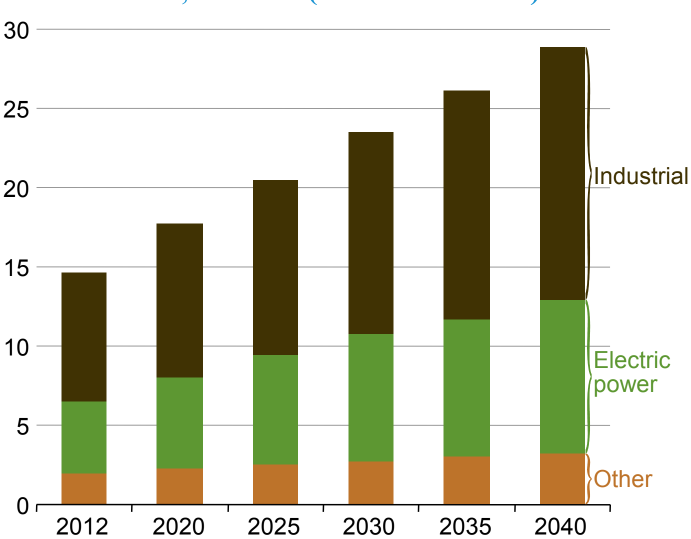
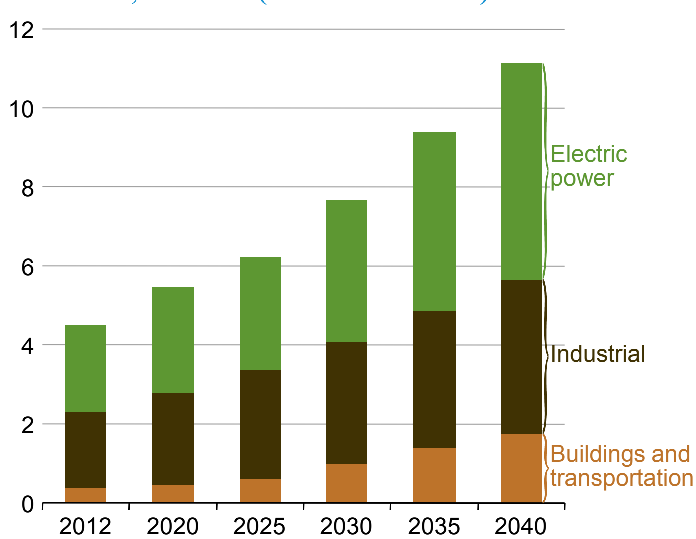



**Figure 3-13. Africa natural gas consumption by end-use sector, 2012–40 (trillion cubic feet)**



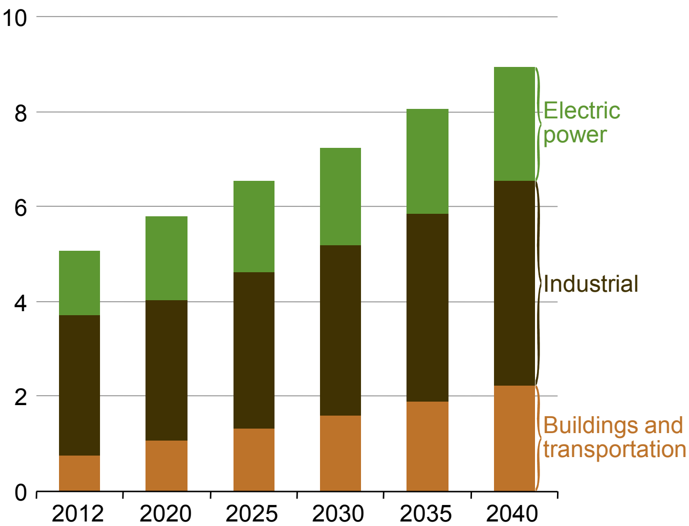

[58] E. Ng, "High prices threaten Beijing's target of natural gas accounting for 10pc of energy use," *South China Morning News: China Business* (June 21, 2015), http://www.scmp.com/business/china-business/article/1824591/high-prices-threaten-beijings-target-natural-gas-accounting.

natural gas in both the industrial and electric power sectors grows by approximately 2.3%/year from 2012 to 2040, when the industrial sector accounts for 64% and the electric power sector accounts for 22% of Brazil's total natural gas consumption.

## World natural gas production

To meet projected growth in natural gas use in the IEO2016 Reference case, the world's natural gas supplies increase by nearly 83 Tcf (69%) from 2012 to 2040. Much of the increase in supply is projected to come from non-OECD countries, which in the Reference case account for 73% of the total increase in world natural gas production from 2012 to 2040. Non-OECD natural gas production grows by an average of 2.1%/year, from 75 Tcf in 2012 to 136 Tcf in 2040 (Table 3-1), while OECD production grows by 1.4%/year, from 44 Tcf to 66 Tcf.

**Figure 3-14. Non-OECD Americas natural gas consumption by end-use sector, 2012–40 (trillion cubic feet)**




Production from continuous resources grows rapidly in the projection, with OECD tight gas, shale gas, and coalbed methane production averaging 3.0%/year, from 20 trillion cubic in 2012 to 47 Tcf in 2040. Over the same period, non-OECD production of tight gas, shale gas, and coalbed methane grows from nearly 2 Tcf to 34 Tcf. However, numerous uncertainties could affect future production of those resources. There is still considerable variation among estimates of recoverable shale gas resources in the United States and Canada, and estimates of recoverable tight gas, shale gas, and coalbed methane for the rest of the world are more uncertain, given the sparse data currently available. Moreover, the hydraulic fracturing process used to produce shale gas resources often requires significant amounts of water, and available water supplies are limited in many of the

**Table 3-1. World natural gas production by region and country in the Reference case, 2012–40 (trillion cubic feet)**

| Region/Country | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change 2012-40 |
|---|---|---|---|---|---|---|---|
| OECD | | | | | | | |
| United States[a] | 24.0 | 28.7 | 30.4 | 32.9 | 34.0 | 35.3 | 1.4 |
| Canada | 6.1 | 5.8 | 6.6 | 7.2 | 7.9 | 8.6 | 1.2 |
| Europe | 10.3 | 8.7 | 9.1 | 10.1 | 11.1 | 11.9 | 0.5 |
| Australia/New Zealand | 2.1 | 3.3 | 4.2 | 5.0 | 5.9 | 7.0 | 4.4 |
| Other OECD | 1.9 | 1.4 | 1.7 | 2.2 | 2.8 | 3.6 | 2.3 |
| **Total OECD** | **44.4** | **47.9** | **52.0** | **57.4** | **61.9** | **66.4** | **1.4** |
| Non-OECD | | | | | | | |
| Russia | 21.8 | 21.9 | 23.4 | 25.9 | 29.3 | 31.8 | 1.4 |
| Europe and Central Asia | 6.7 | 7.0 | 7.0 | 7.3 | 8.1 | 9.1 | 1.1 |
| Iran | 5.6 | 7.4 | 8.7 | 10.1 | 11.4 | 12.4 | 2.9 |
| Qatar | 5.5 | 5.8 | 7.0 | 7.6 | 8.0 | 8.4 | 1.5 |
| Other Middle East | 8.1 | 9.8 | 10.6 | 12.1 | 13.5 | 15.1 | 2.2 |
| North Africa | 5.6 | 7.1 | 7.1 | 7.1 | 7.3 | 7.7 | 1.1 |
| Other Africa | 2.0 | 2.7 | 4.1 | 6.1 | 7.6 | 8.8 | 5.5 |
| China | 3.7 | 7.2 | 11.1 | 14.2 | 16.7 | 18.7 | 6.0 |
| Other Asia | 10.9 | 11.1 | 11.4 | 12.2 | 13.4 | 14.6 | 1.0 |
| Americas | 5.5 | 6.1 | 7.0 | 7.6 | 8.4 | 9.4 | 2.0 |
| **Total Non-OECD** | **75.3** | **86.1** | **97.4** | **110.1** | **123.5** | **136.0** | **2.1** |
| **Total World** | **119.7** | **134.0** | **149.4** | **167.5** | **185.4** | **202.4** | **1.9** |
| Discrepancy[b] | -0.1 | 0.8 | 0.4 | 0.9 | 0.1 | -0.9 | |

[a]Includes supplemental production minus any projection discrepancy.

[b]Balancing item. Differences between global production and consumption totals result from independent rounding and differences in conversion factors derived from heat content of natural gas that is produced and consumed regionally.

world regions that have been identified as possessing shale gas resources. Further environmental concerns can also add to the uncertainty surrounding access to shale gas resources.

## *OECD production*

### *OECD Americas*

Natural gas production in the OECD Americas grows by 49% from 2012 to 2040. The United States, which is the largest producer in the OECD Americas and in the OECD as a whole, accounts for more than two-thirds of the region's total production growth from 24 Tcf in 2012 to 35 Tcf in 2040 (Figure 3-15). U.S. shale gas production grows from 10 Tcf in 2012 to 20 Tcf in 2040, more than offsetting declines in production of natural gas from other sources. In 2040, shale gas accounts for 55% of total U.S. natural gas production in the IEO2016 Reference case, tight gas accounts for 20%, and offshore production from the Lower 48 states accounts for 8%. The remaining 17% comes from coalbed methane, Alaska, and other associated and nonassociated onshore resources in the Lower 48 states.

Natural gas production in Canada grows by 1.2%/year on average over the projection period, from 6.1 Tcf in 2012 to 8.6 Tcf in 2040. In Canada, like in the United States, much of the production growth comes from growing volumes of tight gas and shale gas production.

Mexico's natural gas production is relatively flat in the midterm, but it more than doubles in the later years of the projection, as production from shale gas resources grows, supported by the country's recent energy reforms. Total natural gas production in Mexico increases from 1.7 Tcf in 2012 to 3.3 Tcf in 2040. Like Canada and the United States, Mexico is thought to have substantial shale gas resources, the most prospective of which are extensions of the successful Eagle Ford Shale in the United States. However, because the shale resources in Mexico have not been explored as fully as those in the rest of North America, there is more uncertainty surrounding estimates of their size and potential for production.

### *OECD Europe*

Norway, the Netherlands, and the United Kingdom are the three largest producers of natural gas in OECD Europe, accounting for more than 80% of the region's total natural gas production in 2012. In the IEO2016 Reference case, OECD Europe's natural gas production declines in the mid-term and then begins to grow again in the later part of the projection, as production from tight gas, shale gas, and coalbed methane resources becomes more significant (Figure 3-16). Overall, natural gas production in OECD Europe in 2040 is 1.6 Tcf higher than in 2012. Contributing to OECD Europe's total production is the growth in natural gas production from Israel, which became an OECD member country in September 2010 and is included in OECD Europe for statistical reporting purposes.

### *OECD Asia*

Natural gas production in the Australia/New Zealand region increases from 2.1 Tcf in 2012 to 7.0 Tcf in 2040 in the IEO2016 Reference case, at an average rate of 4.4%/year. In 2012, more than 90% of production in the Australia/New Zealand region came from Australia, with production in Western Australia (including the Northwest Shelf area of Australia's Carnarvon Basin) accounting for approximately 58% of the country's total production.[59] Much of Australia's production is used as feedstock at the

**Figure 3-15. OECD natural gas production by country and region, 2012–40 (trillion cubic feet)**

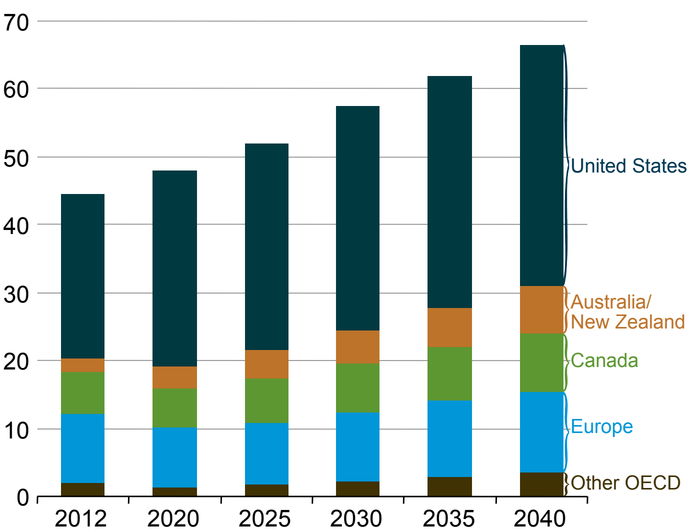
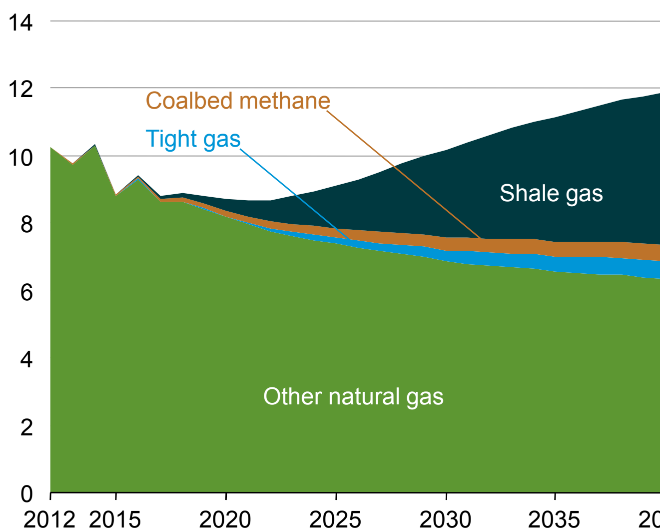



**Figure 3-16. OECD Europe natural gas production, 2012–40 (trillion cubic feet)**




Note: Other gas includes gas produced from structural and stratigraphic traps (e.g., reservoirs), historically called conventional.

[59] U.S. Energy Information Administration, "Australia: International Energy Data and Analysis" (Washington, DC: August 28, 2014), https://www.eia.gov/beta/international/analysis.cfm?iso=AUS.

Northwest Shelf LNG liquefaction facility. Similarly, many of Australia's new natural gas field developments are tied to liquefaction projects that have several export contracts in place.

Both Japan and South Korea have limited natural gas resources. Consequently, they have limited current production and limited prospects for future production. Both countries receive most of their natural gas supplies in the form of imported LNG. In 2012, natural gas production in Japan accounted for only 3% of the country's natural gas consumption, and in South Korea domestic natural gas production accounted for less than 1% of natural gas consumption. Although substantial deposits of methane hydrates in both Japan and South Korea have been confirmed, both countries are investigating how those resources could be safely and economically developed. The IEO2016 Reference case does not include methane hydrate resources in its estimates of natural gas resources, and widespread development of hydrates on a commercial scale is not anticipated during the projection period.

## Non-OECD production

### Middle East

The three largest natural gas producers in the Middle East—Iran, Qatar, and Saudi Arabia—together accounted for 76% of the natural gas produced in the Middle East in 2012. With more than 40% of the world's proved natural gas reserves, the Middle East accounts for 20% of the total increase in world natural gas production in the IEO2016 Reference case, from 19.2 Tcf in 2012 to 35.8 Tcf in 2040 (Figure 3-17).

The strongest growth among Middle East producers from 2012 to 2040 in the IEO2016 Reference case comes from Iran, where natural gas production increases by 6.8 Tcf, followed by Saudi Arabia (3.4 Tcf of new production) and Qatar (2.9 Tcf). Although Iraq is the region's fastest-growing supplier of natural gas, with average increases of 15%/year over the projection period, it remains a relatively minor contributor to regional natural gas supplies. In 2040, Iraq's natural gas production totals 1.0 Tcf, or about 3% of the Middle East total.

### Non-OECD Europe and Eurasia

In the IEO2016 Reference case, 15% of the global increase in natural gas production comes from non-OECD Europe and Eurasia, which includes Russia, Central Asia, and non-OECD Europe. In the region as a whole, natural gas production increases from 28.5 Tcf in 2012 to 40.9 Tcf in 2040 (Figure 3-18). Russia remains the largest natural gas producer, accounting for more than 75% of the region's total production over the projection period. In the IEO2016 Reference case, Russia's natural gas production grows on average by 1.4%/year from 2012 to 2040, supported primarily by growth in exports to both Europe and Asia.

Natural gas production in Central Asia, which includes the former Soviet Republics, grows by 0.9%/year on average, from 5.5 Tcf in 2012 to 7.1 Tcf in 2040. Much of the projected growth is in Turkmenistan, which already is a major natural gas producer, accounting for 44% of the region's total production in 2012. Also contributing to Central Asia's production growth is Azerbaijan. Almost all of Azerbaijan's natural gas is produced in two offshore fields—the Azeri-Chirag-Deepwater Gunashli (ACG) complex and Shah Deniz. The second phase of Shah Deniz development is expected to start producing in 2018, with a peak capacity of 565 Bcf per year (in addition to the 315 Bcf in Phase I), according to BP, the development operator.[60] When it is completed, Shah Deniz will be one of the largest natural gas development projects in the world.

**Figure 3-17. Middle East natural gas production by country, 2012–40 (trillion cubic feet)**

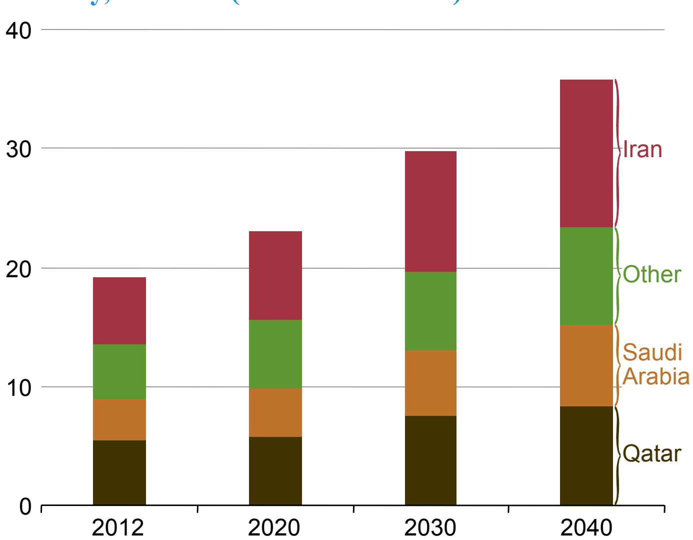
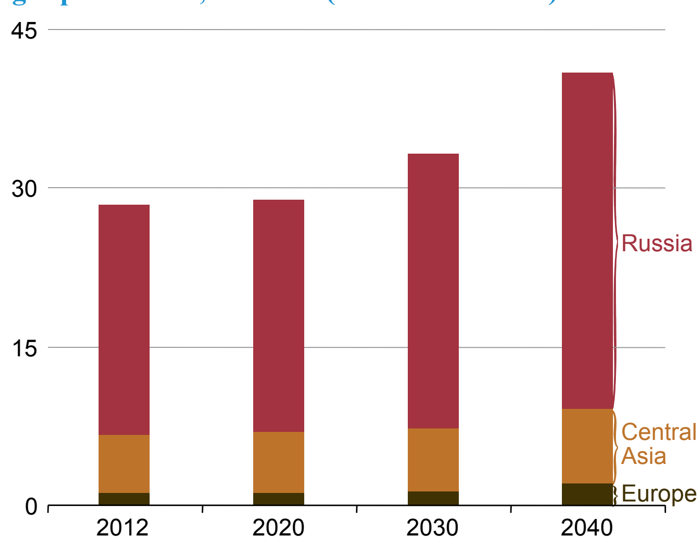



**Figure 3-18. Non-OECD Europe and Eurasia natural gas production, 2012–40 (trillion cubic feet)**




[60]BP, "BP Azerbaijan: Operations and Projects: Shah Deniz Stage 2," BP Azerbaijan (undated), http://www.bp.com/en_az/caspian/operationsprojects/Shahdeniz/SDstage2.html.

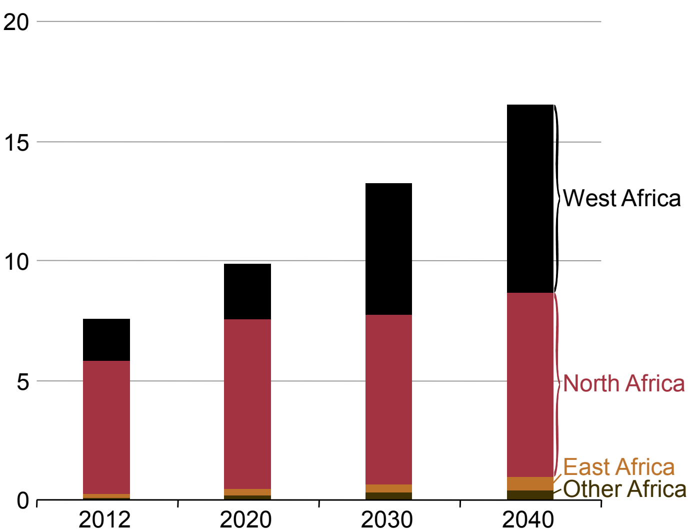
### Africa

Natural gas production in Africa grows in the IEO2016 Reference case from 7.6 Tcf in 2012 to 9.8 Tcf in 2020 and 16.5 Tcf in 2040 (Figure 3-19). In 2012, about three-quarters of Africa's natural gas was produced in North Africa, mainly in Algeria, Egypt, and Libya. West Africa (with Nigeria and Equatorial Guinea providing virtually all of West Africa's production) accounted for another 23% of the 2012 total, and the rest of Africa accounted for 3%. Remaining resources in West Africa are more promising than those in North Africa, which has been producing large volumes of natural gas over a much longer period. Accordingly, in the IEO2016 Reference case, production growth in West Africa is higher than in North Africa, with annual increases over the projection period averaging 5.6%/year and 1.1%/year, respectively.

Nigeria is the largest natural gas producer in West Africa, although there also have been recent production increases in Equatorial Guinea, which brought an LNG liquefaction facility online in 2007. Angola was expected to add to West Africa's production in the near term with the startup of its first LNG liquefaction facility in 2013. However, in April 2014, Angola LNG temporarily shut down the plant because of ongoing technical issues, which led to infrequent exports while it was open. Technical issues at the plant included electrical fires, pipeline leaks and ruptures, and a collapsed drilling rig. Recommissioning of the Angola LNG plant began in January 2016 and operator Chevron expects the first LNG shipment to occur in the second quarter of 2016.[61]

In Nigeria, security concerns and uncertainty over terms of access have delayed proposed export projects and limited mid-term production growth. In the IEO2016 Reference case, export projects in Nigeria regain their former momentum later in the projection period, raising production for the West Africa region from 1.7 Tcf in 2012 to 7.9 Tcf in 2040. West Africa's share of the continent's total natural gas production more than doubles in the IEO2016 Reference case, from 23% in 2012 to 48% in 2040.

**Figure 3-19. Africa natural gas production by region, 2012–40 (trillion cubic feet)**




### Non-OECD Asia

In the IEO2016 Reference case, natural gas production in non-OECD Asia more than doubles from 2012 to 2040, increasing by 18.7 Tcf (Figure 3-20). Growth from production in China accounts for 80% of this increase. From 2012 to 2040, China has the largest increase in natural gas production in non-OECD Asia, from 3.7 Tcf in 2012 to 18.7 Tcf in 2040, growing at an annual average rate of 6.0%. Much of the increase in the latter years comes from tight gas, shale gas, and coalbed methane reservoirs. China already is producing small volumes of coalbed methane and significant volumes of tight gas (Figure 3-21) *(see below, "Shale gas development in China: Government investment and decreasing well costs")*.

**Figure 3-20. Non-OECD Asia natural gas production by source, 2012–40 (trillion cubic feet)**

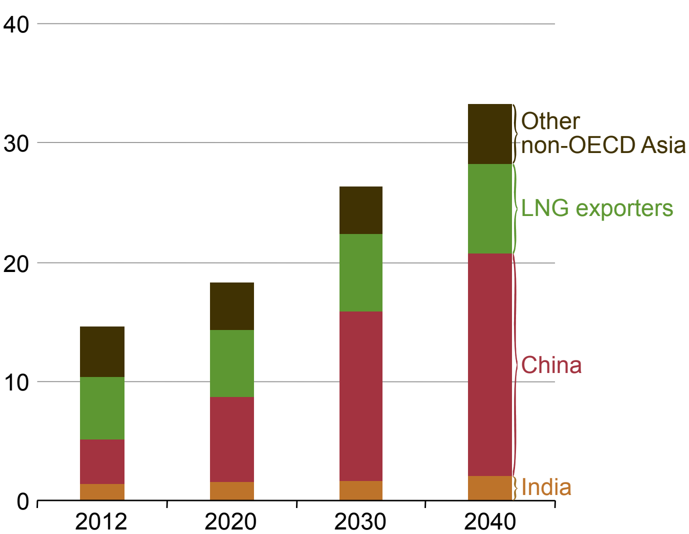
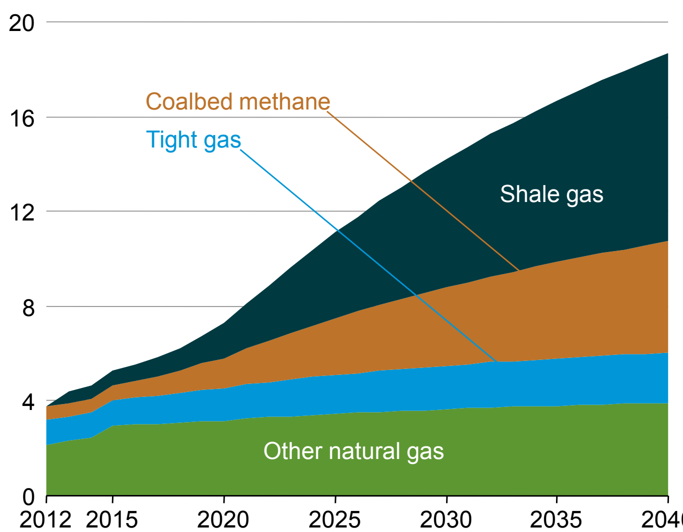



**Figure 3-21. China natural gas production by type, 2012–40 (trillion cubic feet)**




*Other gas includes gas produced from structural and stratigraphic traps (e.g., reservoirs), historically called conventional.*

[61]Chevron CEO: Angola LNG to ship in 2nd quarter," *LNG World News* (February 1, 2016), http://www.lngworldnews.com/chevron-ceo-angola-lng-to-ship-lng-cargo-in-2nd-quarter/.

## Shale gas development in China: Government investment and decreasing well costs

As China continues to invest in domestic oil and gas production, and as the cost of drilling shale gas wells has fallen (Figures 3-22 and 3-23), China's development of shale gas has increased. Although the Chinese energy market has increasingly relied on imported natural gas, future shale gas production could help to meet natural gas demand even as the country faces difficulties in developing other natural gas resources, including coalbed methane (CBM).

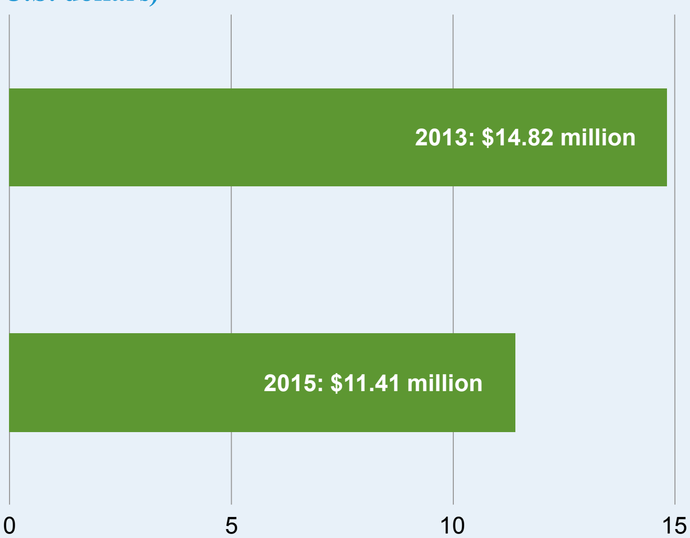
Over the past 25 years, China has worked to develop its substantial CBM resources, estimated by China's Ministry of Land and Resources (MLR) at more than 1,000 Tcf.[62] Commercialization began slowly in the 1990s, with CBM exploration programs operated by foreign companies, including BP, Chevron, and ConocoPhillips. However, the initial wells had low production rates, and by 2000 exploration activity had slowed. Although well performance has not improved much since 2000, the development of CBM supported by government loans and subsidies has accelerated. PetroChina, China United Coalbed Methane Corporation, Jincheng Coal Group, and other Chinese companies have reduced well costs and have benefited from higher natural gas prices. Currently, there are more than 20,000 CBM wells in China, producing a total of 0.36 Bcf/d. However, CBM well productivity in China is significantly lower than in some other countries, including Australia and the United States. CBM development in China has focused on the Ordos and Qinshui basins in Shanxi Province, which are considered to have the country's best geologic conditions, but significant geologic challenges—including low permeability and undersaturation—have constrained well productivity.

The difficulty of increasing CBM output has led China to increase its efforts to develop shale gas resources, taking an approach similar to that used for CBM development. China's technically recoverable shale gas resources are estimated at 1,115 Tcf.[63] The amount that becomes economically recoverable will depend on the market price of natural gas from foreign sources, including both pipeline gas and liquefied natural gas, as well as the capital and operating costs and productivity of shale gas production in China. More than 700 shale gas wells have been drilled in China over the past 4 years, and production has reached 0.38 Bcf/d.

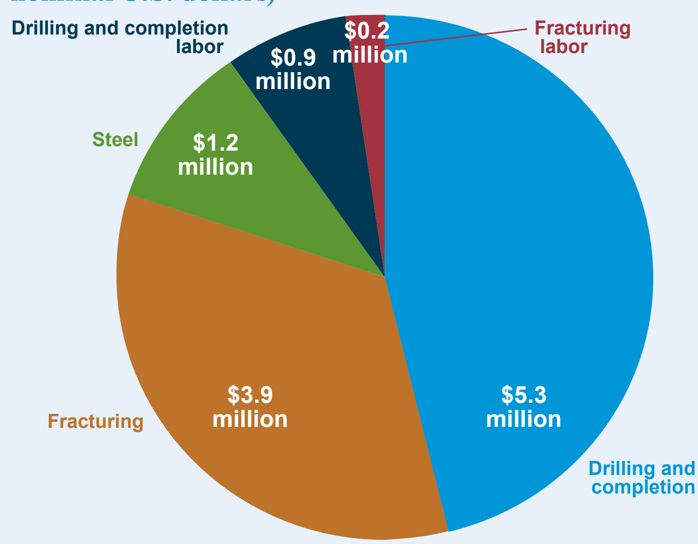
As Chinese companies have gained experience in shale gas production, their drilling costs have declined. According to China National Petroleum Corporation's Economics and Technology Research Institute, the cost of drilling in shale formations in the

*(continued on page 48)*

### Figure 3-22. Cost of drilling a shale gas well in the Sichuan Basin, 2013 and 2015 (million nominal U.S. dollars)




### Figure 3-23. Cost components of shale gas well development in the Sichuan Basin, 2015 (million nominal U.S. dollars)




Note: Component costs are based on the EIA/ARI component-based cost model, which assumes average well depth of 11,500 feet with 4,000 feet of horizontal drilling. Cost data for 2013 are based on reports from Platts October 2013 reporting statements by Ma Yongshen, Sinopec chief geologist. Cost data for 2015 are based on statements from China National Petroleum Corporation's Economics and Technology Research Institute at the Third IEA Unconventional Gas Forum in Chengdu, China, in April 2015.

[62] Liu Chenglin, Che Changbo, Fan Mingzhu, Zhu Jie, and Yang Hulin, "China CBM Geology and Resources Evaluation," *China Coalbed Methane* (2009), http://www.nios.com.cn/common/files/File/2009.03-English.pdf.

[63] U.S. Energy Information Administration, "World Shale Resource Assessments" (Washington, DC: September 24, 2015), http://www.eia.gov/analysis/studies/worldshalegas/.

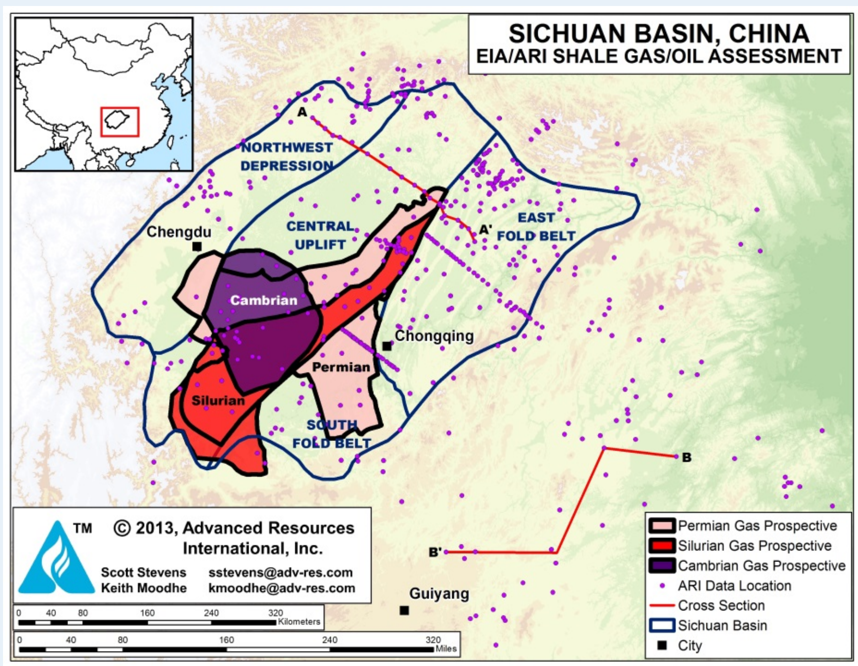
Sichuan Basin was between $11.3 million and $12.9 million per well in mid-2015[64]—23% lower than the cost cited in 2013 reports from Sinopec, another Chinese national oil company.[65]

China has also invested heavily in joint ventures in U.S. shale plays, with its financial involvement representing 20% of total foreign investment in U.S. shale plays.[66] This investment likely has provided China with valuable expertise that can be applied to its own domestic production, helping to lower well development costs.

Decreasing well costs and increasing experience in developing shale gas have been supplemented by continued government investment in the development of shale gas. In 2012, to encourage shale gas exploration, China's government established a four-year subsidy program for any Chinese company achieving commercial production of shale gas, with subsidies of $1.80 per million British thermal units. The subsidies were extended in mid-2015, at a lower rate, through 2020.[67] Initially, shale gas development has been focused on the Longmaxi formation in the Sichuan Basin (Figure 3-24), which is estimated to hold 287 Tcf of technically recoverable volumes.[68]

According to MLR, Sinopec and PetroChina are on schedule to reach 0.6 Bcf/d of shale gas production by the end of 2015. Although it is still a small fraction of China's overall production, which was estimated at 13.0 Bcf/d in 2014,[69] shale gas eventually could help to meet growing demand for natural gas in China and limit growth in the country's natural gas imports.

**Figure 3-24. EIA/ARI assessment of shale gas and tight oil resources in China's Sichuan Basin**




Natural gas production in India grows by an average of 1.3%/year in the IEO2016 Reference case, from 1.4 Tcf in 2012 to 2.1 Tcf in 2040. India faces several production challenges. For example, a large portion of its current production comes from aging western offshore fields, and production volume from the Krishna Godavari Basin—located off India's eastern coast—has failed to meet earlier expectations. India has several basins that are prospective for shale gas. India's oil ministry has announced that the government will unveil a shale gas and oil policy in the near future and begin selling shale gas development blocks, although no

[64]International Energy Agency, "3rd IEA Unconventional Gas Forum" (Chengdu, China: April 10, 2015), https://www.iea.org/workshops/3rd-iea-unconventional-gas-forum.html.

[65]Reported by Platts (quoting Mr. Ma Yongsheng, Sinopec's Chief Geologist in China) in October 2013, for a horizontal well at Fuling field in the Sichuan Basin.

[66]U.S. Energy Information Administration, "Foreign investors play large role in U.S. shale industry" (Washington, DC: April 8, 2013), http://www.eia.gov/todayinenergy/detail.cfm?id=10711.

[67]IHS Energy, "Market Briefing, China Oil and Gas Service, China Upstream Market Briefing Second Quarter 2015" (July 2015), https://www.ihs.com/products/cera-china-energy-research.html (subscription site).

[68]U.S. Energy Information Administration and Advanced Resources International, Inc., *World Shale Gas and Shale Oil Resource Assessment* (June 26, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=21832; and U.S. Energy Information Administration/Advanced Resources International, Inc., *EIA/ARI World Shale Gas and Shale Oil Resource Assessment: Technically Recoverable Shale Gas and Shale Oil Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Fairfax, VA: June 2013), http://www.adv-res.com/pdf/A_EIA_ARI_2013%20World%20Shale%20Gas%20and%20Shale%20Oil%20Resource%20Assessment.Pdf.

[69]BP, *BP Statistical Review of World Energy June 2015* (London, UK: June 2015), http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf.

awards have been made to date. In the later years of the IEO2016 Reference case, shale resources provide nearly one-quarter of India's total natural gas production.

### *Non-OECD Americas*

Natural gas production in the non-OECD Americas region nearly doubles in the IEO2016 Reference case, from 5.5 Tcf in 2012 to 9.4 Tcf in 2040 (Figure 3-25). Brazil's natural production grows by an average of 4.0%/year and triples from 0.6 Tcf in 2012 to 1.8 Tcf in 2040. As a result, Brazil's share of regional production increases from 11% in 2012 to nearly 19% in 2040. More than one-third of Brazil's natural gas production growth from 2012 to 2040 comes from tight gas, shale gas, or coalbed methane production. Recent discoveries of oil and natural gas in the presalt Santos Basin are expected to increase the country's natural gas production, particularly in the Tupi field, which could contain between 5 Tcf and 7 Tcf of recoverable natural gas.[70]

Despite recent declines in natural gas production, countries in the Southern Cone (mainly, Argentina) become the region's leading natural gas producers by 2040 in the IEO2016 Reference case, with annual production in the Southern Cone growing by nearly 150%, from 1.3 Tcf in 2012 to 3.1 Tcf in 2040. All of the production increase in the Southern Cone comes from tight gas, shale gas, or coalbed methane gas fields, as production from other resources[71] declines over the projection period. Currently, Argentina leads the non-OECD Americas region in its pursuit of tight gas and shale gas development.

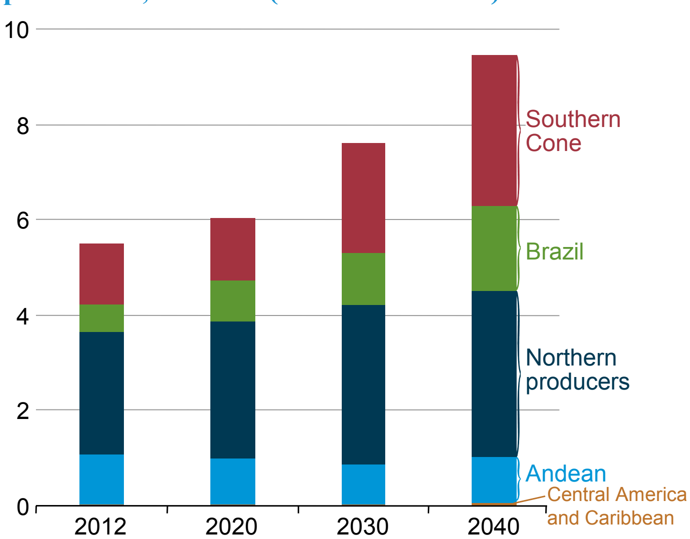
While the growth of natural gas production in Brazil and in the Southern Cone increases natural gas production in the non-OECD Americas region overall, production from the Northern Producers (primarily, Colombia, Venezuela, and Trinidad and Tobago) grows by an average of 1.1%/year, which is the region's second-lowest rate of production increase, after the Andean producers (Bolivia, Ecuador, and Peru). Venezuela's 198 Tcf of proved natural gas reserves are the Western Hemisphere's second-largest reserves, after the United States. An estimated 90% of Venezuela's natural gas reserves are associated, meaning that they are co-located with oil reserves. Although Venezuela has plans to increase its production of nonassociated gas, largely through the development of its offshore reserves, those plans have been delayed by a lack of capital and foreign investment.

## World natural gas trade

International trade in natural gas is undergoing rapid transformation. From 2000 to 2012, global LNG trade more than doubled, from less than 5 Tcf/year to more than 12 Tcf/year, and its growth continues in the IEO2016 Reference case through 2020 as new liquefaction capacity comes online. World LNG flows adjusted quickly in 2011 and 2012, to accommodate a surge in Japan's demand for LNG in the wake of the Fukushima disaster and to account for the underutilization of LNG liquefaction capacity in North Africa and Southeast Asia. As nuclear capacity in Japan is restored, world LNG markets are expected to loosen in the near term because of growing supply and weakening demand.

Although LNG trade has grown considerably in recent years, flows of natural gas by pipeline still account for most of the global natural gas trade in the IEO2016 Reference case, which includes several new long-distance pipelines and expansions of existing infrastructure through 2040. The largest volumes of natural gas traded internationally by pipeline currently are in North America (between Canada and the United States) and in Europe (among many OECD and non-OECD countries). By the end of the projection period, the IEO2016 Reference case includes large volumes of pipeline flows into China from both Russia and Central Asia *(see "Global LNG trade and supply," below)*.

**Figure 3-25. Non-OECD Americas natural gas production, 2012–40 (trillion cubic feet)**




## Global LNG trade and supply

In 2014, natural gas accounted for 25% of the energy used worldwide, with LNG accounting for 10% of global natural gas consumption and 31% of global natural gas trade. From 2005 to 2014, LNG trade increased by an average of 6%/year, nearly twice the growth rate (3.3%/year) of pipeline natural gas trade.[72] In 2015, LNG trade continued to expand, by about 3%, with new liquefaction capacity additions in Australia and Indonesia.[73] In the IEO2016 Reference case, world LNG trade expands by

*(continued on page 50)*

[70]G. Duffy, "'Huge' gas field found off Brazil," BBC News (Sao Paulo, Brazil: January 22, 2008), http://news.bbc.co.uk/2/hi/americas/7201744.stm.
[71]Other includes gas produced from structural and stratigraphic traps (e.g., reservoirs), historically called conventional.
[72]BP Statistical Review of World Energy, 64th edition (June 2015), https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf.
[73]Based on preliminary estimates from IHS Strategic Report, "Global Gas in 2016, The tipping of the scales" (February 2016), www.ihs.com (subscription site).

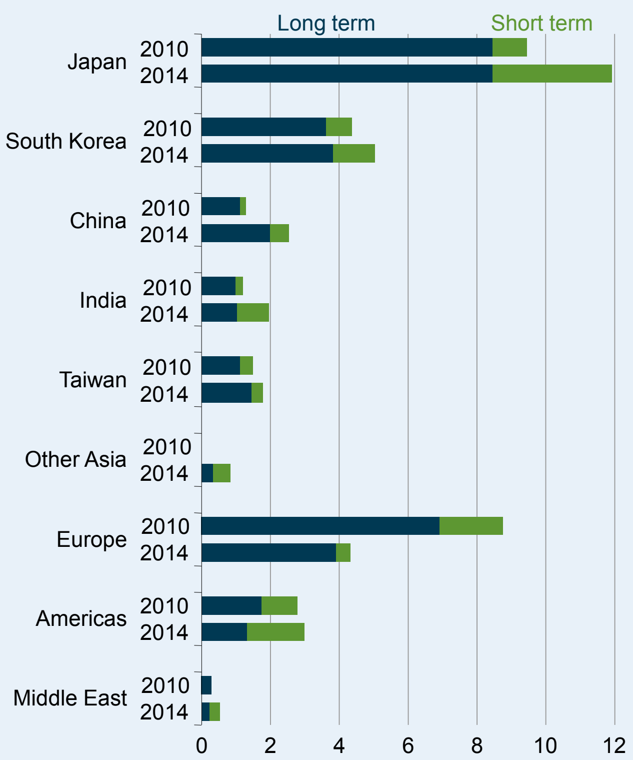
nearly one-third from 2012 to 2020, as large volumes of new liquefaction capacity come online and as more countries opt for LNG as a flexible source of support for their energy systems, particularly where access to natural gas by pipeline may be limited by geographic or economic conditions.

Strong growth in overall global LNG trade over the past 10 years has been accompanied by even stronger growth in LNG trade on spot[74] and short-term[75] markets. Short-term and spot trade in LNG, which in 2000 accounted for less than 5% of the natural gas traded worldwide, grew from 2.5 billion cubic feet per day (Bcf/d) in 2005 to 9.3 Bcf/d in 2014, and its share of total LNG trade increased from 13% to 29%. The growth of short-term and spot LNG trade was aided by a number of developments, including LNG contracts with destination flexibility, decisions by importing countries to procure LNG without long-term contracts, large pricing differentials between the Atlantic and Pacific basins (which supports interbasin arbitrage), a proliferation of LNG marketers with flexible supply portfolios, and an increase in LNG carriers available for spot and short-term charter. The number of countries entering LNG trade has also increased considerably, contributing to the development of more flexible trading patterns between exporters and importers.

The Asia Pacific region,[76] which accounted for almost one-third of world natural gas trade and three-fourths of LNG trade in 2014,[77] led the world growth in LNG demand over the past decade. From 2010 to 2014, as Japan, South Korea, China, and India experienced strong growth in demand for LNG, they sought to supplement contracted volumes with short-term and spot purchases. In addition, delays in the commissioning of new supply projects also contributed to the market tightness. Combined demand for short-term LNG from the four countries nearly tripled, from 2.1 Bcf/d in 2010 to 6.1 Bcf/d in 2014. In Japan alone, short-term market demand increased by 2.5 Bcf/d, while demand for long-term contracts increased by only 1.2 Bcf/d (Figure 3-26).

While demand for LNG in the Asia Pacific region has grown over the past 5 years, demand in Europe has declined. European nations imported a total of 8.7 Bcf/d of LNG in 2010, with short-term demand accounting for 21% of the total; in 2014, their imports totaled 4.3 Bcf/d. European LNG trade was characterized by strong growth in re-exports, primarily to Asia. Of the total volume of short-term LNG purchases imported to Europe in 2014 (1.2 Bcf/d), three-quarters was re-exported to countries in Asia, the Middle East, and South America.

**Figure 3-26. Global LNG trade by contract type, 2010 and 2014 (billion cubic feet per day)**




Note: LNG imports to Europe are shown as net of re-exports.

From 2008 to 2014, 12 countries became LNG importers: 4 in Asia (Thailand, Singapore, Malaysia, and Indonesia), 3 in South America (Argentina, Brazil, and Chile), 3 in the Middle East (Dubai, Kuwait, and Israel), and 2 in Europe (the Netherlands and Lithuania). Together they accounted for 9% (3 Bcf/d) of the world's total LNG imports in 2014. Most of those 12 countries are relatively small markets that opted for floating regasification units (FSRU) as a fast and cost-effective way to meet growing demand for natural gas. Most of the 12 countries have flexible seasonal demand and procure LNG primarily in the spot market. In 2014, spot and short-term imports accounted for three-quarters of their combined total LNG imports. In 2015, four additional countries became LNG importers,[78] and three of them—Egypt, Pakistan, and Jordan—opted for floating regasification. In 2016, Colombia and Uruguay are expected to begin LNG imports using FSRU as receiving terminals.

Qatar maintained its position as the world's leading supplier of both spot and long-term LNG volumes in 2015, and it is expected to hold that spot until the end of the decade, when both the United States and Australia are expected to close the gap. However, although Qatar holds abundant reserves of natural gas, its government has chosen to continue a self-imposed moratorium on development of its North Field and construction of new LNG export facilities. No new projects are expected in Qatar until 2020 or later.

*(continued on page 51)*

[74]Generally, spot trade implies a single transaction between a buyer and a seller.

[75]Short-term contracts have a duration of 4 years or less.

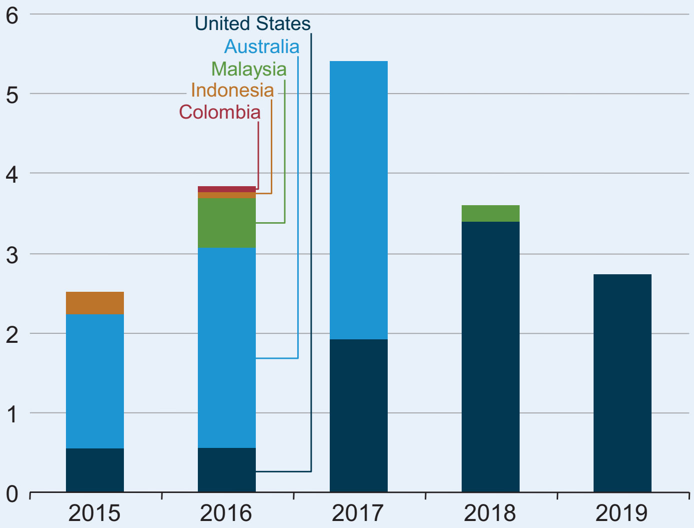
[76]The Asia Pacific region includes Australia, China, India, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand.

[77]*BP Statistical Review of World Energy,* 64th edition (June 2015), https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf.

[78]U.S. Energy Information Administration, "Floating LNG regasification is used to meet rising natural gas demand in smaller markets" (Washington, DC: April 27, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=20972.

Although Malaysia was the world's second-largest exporter of LNG in 2014, both Australia and the United States are on track to surpass Malaysia in the near future, with liquefaction projects already under construction and expected to enter service by 2020. In the IEO2016 Reference case, global liquefaction capacity in 2019 reaches 57 Bcf/d, a 32% increase from 2015, led by capacity additions in Australia and the United States that together account for 93% of the new liquefaction capacity coming online over the 2015–19 period (Figure 3-27).

**Figure 3-27. Global LNG capacity additions by country, 2015–19 (billion cubic feet per day)**




Note: Nameplate capacity is shown, not adjusted for ramp-up.

Australia, already a significant player in the LNG industry, exported 3.2 Bcf/d of LNG in 2014 and brought the first of its seven new projects—Queensland Curtis LNG Train 1[79]—online in late 2014 and Train 2 in mid-2015. Six additional projects are under construction and are scheduled to come online by 2018. With this growth, Australia is expected to overtake Qatar as the world's leading LNG exporter with 11.5 Bcf/d of liquefaction capacity by 2019. In the United States, five liquefaction facilities are currently under construction, and the first export cargo from the Lower 48 states was shipped in February 2016. Several additional projects in the United States are well into the planning and application process.

The short-term outlook for LNG trade points to a potential oversupply, as it will take some time for the market to absorb the large volumes of new LNG supply coming online. In the midterm, new liquefaction projects on the east coast of Africa (Mozambique, Tanzania) and in western Canada, and offshore floating liquefaction projects in Malaysia and Australia will be considered as the LNG market moves beyond its traditional supply sources. In the long term, the number of LNG exporters and importers is expected to continue growing as projects move to more remote areas.

### *OECD natural gas trade*

In 2012, 23% of the natural gas demand in OECD nations was met by net imports from non-OECD countries. That share falls to 16% in 2040 in the IEO2016 Reference case, with both imports and exports from different OECD regions shifting substantially over the projection period. As exports of LNG from the United States and Australia increase in the first decade of the projection period, total net imports to the OECD—predominantly to Europe, Japan, and South Korea—begin to decline after 2016. Over the entire period from 2012 to 2040, net imports of LNG to the OECD fall in the IEO2016 Reference case by 0.4%/year, and net imports in 2040 are 13% lower than they were in 2012.

## Liquefied natural gas: Growing use of floating storage and regasification units

Floating regasification is a flexible, cost-effective way for smaller markets to receive and process LNG shipments. Several countries have turned to floating regasification as a short-term solution to meet growing demand for natural gas. Three of the four countries that began importing LNG in 2015—Pakistan, Jordan, and Egypt—are using floating regasification rather than building full-scale onshore regasification facilities. In addition, the technology is being used in other countries as a temporary solution while onshore facilities are being built.

Floating regasification involves the use of a specialized vessel—a floating storage and regasification unit (FSRU), which is capable of transporting, storing, and regasifying LNG onboard—and either an offshore terminal, which typically includes a buoy and connecting undersea pipelines to transport regasified LNG to shore, or an onshore dockside receiving terminal. An FSRU can be either purpose-built or converted from a conventional LNG vessel. The technology can be developed in less time than an onshore facility of comparable size. As of 2015, 18 FSRUs were functioning as both transportation and regasification vessels, and 5 permanently moored regasification units had been converted from conventional LNG vessels to FSRUs.

The use of floating regasification has grown rapidly in recent years (Figures 3-28 and 3-29), particularly in emerging markets facing short-term supply shortages. The technology was first deployed in the U.S. Gulf of Mexico in 2005. Floating regasification capacity totaled 7.8 billion cubic feet per day (Bcf/d) at the end of 2014, representing 8% of global installed regasification capacity, according to data from the International Gas Union.

*(continued on page 52)*

[79]Australian Petroleum Production & Exploration Association, "Australian LNG projects" (not dated), http://www.appea.com.au/oil-gas-explained/operation/australian-lng-projects/.

In the spring and fall of 2015, four more floating terminals came online—one each in Pakistan and Jordan and two in Egypt—adding 1.9 Bcf/d of new capacity.[80] Seven more floating regasification terminals, totaling 3.1 Bcf/d capacity, are being developed in Uruguay, Chile, Ghana, India, the Dominican Republic, Puerto Rico, and Colombia, with expected online dates in 2016–17. When those terminals are completed, global regasification capacity will total 12.7 Bcf/d.

Floating regasification is likely to remain a preferred technology option for emerging markets because of its flexible deployment capabilities, smaller capacities, quick startup, and relatively low costs as compared with the costs of onshore terminals.

**Figure 3-28. Floating LNG regasification share of total world regasification capacity, 2006–16 (billion cubic feet per day)**

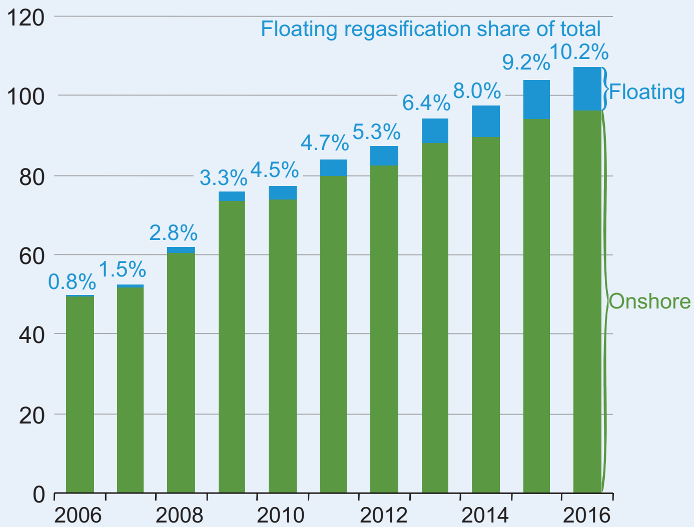
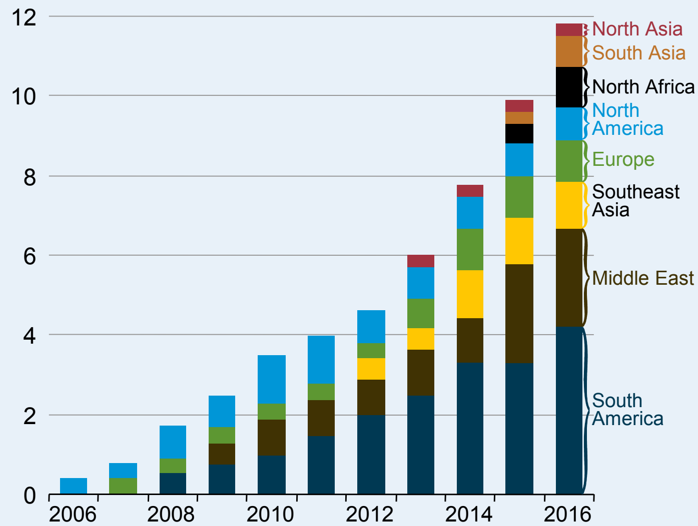


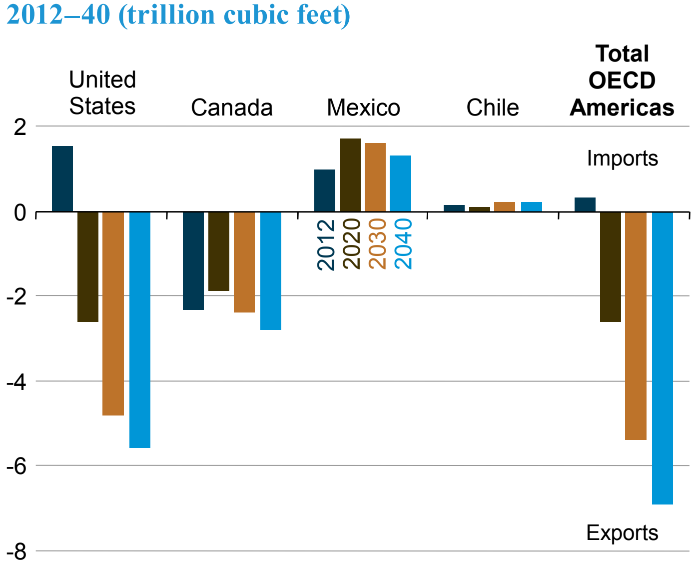

**Figure 3-29. Floating LNG regasification capacity by region, 2006–16 (billion cubic feet per day)**




### *OECD Americas*

With the exception of Mexico, regional net imports among the nations of the OECD Americas trend downward through 2040 in the IEO2016 Reference case (Figure 3-30). In the United States, rising domestic production reduces the need for imports, primarily as a result of robust growth in regional production of shale gas. The United States becomes a net exporter of natural gas in 2017, with net exports growing to 5.6 Tcf in 2040. Most of the growth in U.S. net exports can be attributed to exports of LNG globally, although U.S. pipeline exports to Mexico also grow steadily as increasing volumes of natural gas for Mexico imported from the United States fill the growing gap between production and consumption in Mexico. In 2012, U.S. exports to Mexico totaled 620 billion cubic feet. In the IEO2016 Reference case, Mexico's net natural gas imports more than double, to 1.3 Tcf in 2040, after reaching their highest level in the mid-2020s. Beyond 2025, increases in Mexico's natural gas production slow the country's demand for imports *(see "U.S. natural gas exports to Mexico," below).* U.S. domestically sourced exports of LNG (excluding exports from the existing Kenai facility in Alaska) begin in 2016 and grow to 3.4 Tcf in 2030, with more than three-quarters originating in the Lower 48 states and the remainder in Alaska.

**Figure 3-30. OECD Americas net natural gas trade, 2012–40 (trillion cubic feet)**




In the IEO2016 Reference case, pipeline exports of natural gas from Canada to the United States continue declining as U.S. shale gas production grows. However, Canada remains a net exporter of natural gas, with LNG export volumes replacing some of the lost pipeline export volumes. Canada's net exports of natural gas in 2040 in the IEO2016 Reference case are 22% higher than they were in 2012.

[80]International Gas Union, *2016 World LNG Report* (Fornebu, Norway: 2016), p. 5, http://www.igu.org/publications/2016-world-lng-report.

## U.S. natural gas exports to Mexico

With new U.S. pipeline export capacity being brought online, and connecting pipelines in Mexico ramping up to full capacity, exports of natural gas by pipeline from the United States are beginning to gradually displace Mexico's imports of LNG. According to EIA data, U.S. pipeline exports to Mexico set a monthly record high average of 3.3 billion cubic feet per day (Bcf/d) in July 2015, and over the first seven months of 2015 they averaged 2.7 Bcf/d—35% higher than the total for the first seven months of 2014. Mexico's LNG imports declined in the first seven months of 2015, according to data from the Secretaría de Economía. Before the boom in U.S. shale gas production, Mexico had expected only limited growth in pipeline imports from the United States. However, with the rise of U.S. shale production and the decline in natural gas prices, Mexico's need for LNG imports has fallen, and its LNG regasification terminals have been operating below capacity.

Currently, Mexico has three regasification terminals: Altamira, on the east coast, commissioned in 2006, with 0.7 Bcf/d capacity; Ensenada (also called Energia Costa Azul) on the west coast in operation since 2008 with 1.0 Bcf/d capacity; and Manzanillo on the west coast commissioned in 2012 with 0.5 Bcf/d capacity. While use at the Manzanillo terminal has been relatively high, averaging 85% in 2013–14, utilization at the Altamira terminal averaged around 50%, and the Costa Azul terminal in the Baja Peninsula was virtually unused.

LNG imports at the Manzanillo terminal provide natural gas for the gas-fired power plants in Mexico's Central West region. The location of the Manzanillo terminal provides a unique point of entry and serves to relieve pipeline bottlenecks in the region. As a result, LNG imports to the terminal are expected to remain high over the next few years, until additional pipeline capacity is developed to provide alternative sources.

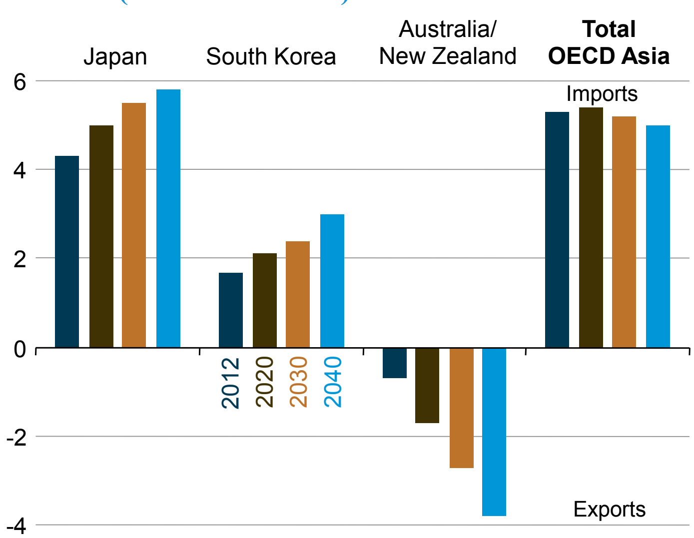
Imports at the Energia Costa Azul terminal, on the other hand, have averaged only 4% of the terminal's nameplate capacity since 2011, despite a long-term contract with the Tangguh liquefaction project in Indonesia. Originally, the terminal was constructed to supply the Southern California market and new power plants in Mexico's state of Baja California. However, those plants also could be supplied via U.S. pipelines, and the terminal depended mostly on natural gas demand in California, which was limited by the availability of less costly U.S. supplies. Because the Costa Azul contract allowed for diversion of supply volumes to other markets, most of contracted supply from Indonesia has gone instead to higher priced Asian markets over the past several years. Sempra Energy, the terminal's operator, is considering a conversion of the terminal to a liquefaction facility.

At the Altamira terminal, LNG imports in 2008–15 have consistently averaged about 50% of the terminal's capacity. Terminal operators Shell and Total have a supply contract with Mexico's Comisión Federal de Electricidad (CFE), which allows them to supply CFE with either pipeline natural gas or LNG. However, the contract stipulates that at least 50% of the supply must be LNG. In the first six months of 2015, imports to the Altamira terminal declined by 14% from the same period a year earlier, as increasing availability of pipeline gas from the United States at lower prices displaced some of the LNG imports. In September 2015, CFE canceled a tender for several spot cargos into Altamira between September and December, noting the increased availability of less-expensive pipeline natural gas from the United States. The Manzanillo terminal may follow suit in the coming years as additional pipeline infrastructure becomes available in the region to alleviate the existing bottlenecks.

### *OECD Europe*

In OECD Europe, total natural gas imports continue to grow by an average of 2.1%/year from 2012 to 2040 as local production sources decline, especially in the United Kingdom. The pipeline share of OECD Europe's natural gas imports grows in the IEO2016 Reference case to between 40% and 50% of the region's total natural gas supply, and its LNG imports grow to about 20% of the region's total natural gas supply in 2040.

**Figure 3-31. OECD Asia net natural gas trade, 2012–40 (trillion cubic feet)**




### *OECD Asia*

The world's two largest importers of LNG are Japan and South Korea in the OECD Asia region. The Australia/New Zealand country grouping, also in OECD Asia, is becoming the world's second-largest exporter of LNG (after Qatar). Supported by a fivefold increase in Australia's exports from 2012 to 2040, OECD Asia's net demand for imports falls from 5.3 Tcf in 2012 to 5.0 Tcf in 2040 (Figure 3-31).

Japan and South Korea continue to be major players in world LNG trade, even though their total consumption of natural gas is relatively small on a global scale. Although their combined natural gas consumption represented slightly more than 5% of world consumption in 2012, it represented almost 50% of world LNG imports. Because the two countries are almost entirely dependent on LNG imports for natural gas supplies, their overall consumption patterns translate directly to import requirements. South Korea's imports grow moderately in the IEO2016 Reference case, in line with the country's growth in natural gas demand.

Japan has experienced dramatic growth in LNG imports since the Fukushima nuclear disaster in early 2011, with total LNG imports in 2012 approximately 25% higher than in 2010. Beginning in 2015, there has been a gradual restart of Japan's nuclear capacity, and in the IEO2016 Reference case, those gradual restarts are assumed to continue and to lessen the country's need for LNG imports. When nuclear power generators are able to provide about 15% of Japan's total generation, the country's natural gas import demand is expected to return to the slow growth trend anticipated before the Fukushima event, based on relatively slow economic growth and declining population.

## *Non-OECD natural gas trade*

Net exports of natural gas from non-OECD countries decline by less than 1.0%/year on average in the IEO2016 Reference case. As with the OECD countries, the relatively small decline for the region in aggregate obscures changes in the trading patterns of the separate non-OECD regions and countries.

### *Non-OECD Europe and Eurasia*

Net exports of natural gas from Russia, the largest exporter in the world, represent the most significant factor in exports from non-OECD Europe and Eurasia, which grow in the IEO2016 Reference case by an average of 3.7%/year, from 5.4 Tcf in 2012 to 6.5 Tcf in 2020 and 15.0 Tcf in 2040 (Figure 3-32). With Russia providing the largest incremental volume of exports to meet the increase in demand for supplies from non-OECD Europe and Eurasia, its net exports grow by an average of 3.4%/year, from 6.1 Tcf in 2012 to 15.6 Tcf in 2040. LNG and pipeline exports from Russia to customers in both Europe and Asia increase throughout the projection, while exports from Central Asia increase by an average of 0.3%/year.

### *Middle East*

Net exports of natural gas from the Middle East grow by an average of 1.7%/year, as flows from the region increase from 4.4 Tcf in 2012 to 7.2 Tcf in 2040 (Figure 3-33). An important factor in the increase is the growth of LNG supplies from Qatar after 2025. Qatar's natural gas exports grow by an average of 1.2%/year from 2010 to 2040 in the IEO2016 Reference case. With the current moratorium on further development of Qatar's North Field, no new LNG projects are being initiated. Qatar enacted the moratorium in 2005 to assess the effect of ongoing increases in production on the North Field before committing to further increases.

Iran is another Middle Eastern country that is expected to increase its natural gas exports over the projection period. Net natural gas exports from Iran grow from 0.1 Tcf in 2012 to 2.0 Tcf in 2040 according to the IEO2016 Reference case. International sanctions against Iran's oil and natural gas sectors have been eased as a result of the Joint Comprehensive Plan of Action (JCPOA) agreement reached between Iran, the P5+1 (the five permanent members of the United Nations Security Council and Germany), and the European Union (EU). The JCPOA agreement has the potential to increase Iran's natural gas exports (both by pipeline and, in the longer term, LNG) beyond the amount projected in the IEO2016 Reference case *(see also "Potential for increased natural gas exports from Iran following the end of international sanctions," below)*.

**Figure 3-32. Non-OECD Europe and Eurasia net natural gas trade, 2012–40 (trillion cubic feet)**

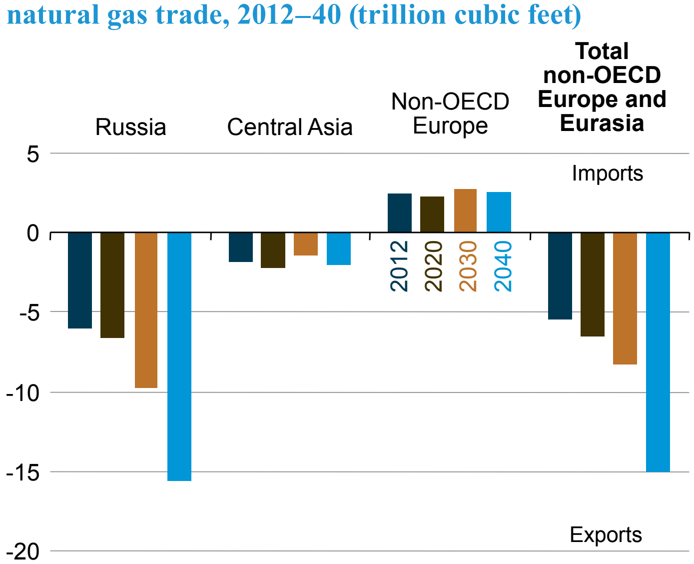
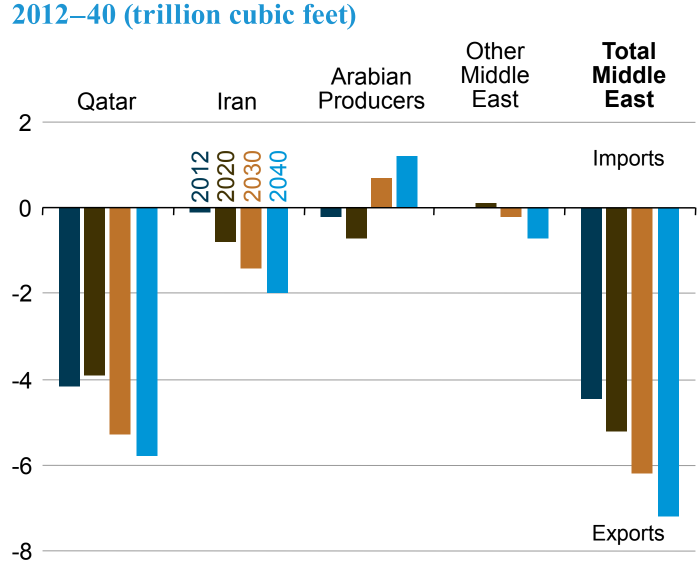



**Figure 3-33. Middle East net natural gas trade, 2012–40 (trillion cubic feet)**



## Potential for increased natural gas exports from Iran following the end of international sanctions

After Russia, Iran has the second-largest proved reserves of natural gas in the world,[81] and it has a strong potential to develop those resources at a faster pace after the recent lifting of nuclear-related sanctions. Iran is targeting a substantial increase in natural gas production in the coming years, not only to meet rapidly growing domestic demand, but also to boost its export capacity, primarily by pipeline. In the longer term, Iran plans to build LNG export facilities for global shipments of natural gas.

Additional production of natural gas for export markets will compete with Iran's domestic demand for natural gas, which is used both for reinjection in the production of oil and as a feedstock in the country's rapidly growing domestic petrochemical industry. According to estimates by the National Iranian Gas Company (NIGC), more than $100 billion in investment capital will be needed to rebuild Iran's natural gas industry.

Iran is currently the fourth-largest natural gas consumer in the world after the United States, Russia, and China, with total consumption of 15.4 Bcf/d in 2014[82] and 16.6 Bcf/d in the first 6 months of 2015. From 2005 to 2014, Iran's domestic consumption of natural gas grew by 66%, second only to the rate of increase in China.[83]In 2014, Iran's natural gas production and consumption were closely matched, with net exports of 0.1 Bcf/d. In 2014, the residential, commercial, and public sectors and small industries accounted for 55% (8.4 Bcf/d) of Iran's total natural gas consumption. Power plants and large industries accounted for 45% (7.0 Bcf/d) of Iran's total natural gas consumption in 2014. According to NIGC's Strategic Objectives document, Iran plans to increase the natural gas share of its domestic energy mix and more than double its natural gas processing capacity, from approximately 20 Bcf/d in 2014 to 42 Bcf/d by 2025,[84] while reducing its consumption of fuel oil in power generation and replacing its aging oil-fired plants with new natural gas-fired plants.

NIGC estimates that to meet the rapidly growing domestic demand for natural gas, Iran will need more than $20 billion in investment to upgrade and expand its domestic pipeline infrastructure. Iran plans to expand the domestic pipeline network to more than 35 Bcf/d by 2017, adding 1,709 miles (2,750 km) of new pipelines at a cost of $6.3 billion and investing more than $15 billion in expansion and upgrades of the existing domestic pipeline network. Those expansions are likely to require foreign capital, and to attract foreign investors Iran has proposed various investment schemes, including *build-operate-own-transfer.* Some foreign investors may be reluctant to proceed at this point because of concerns about corruption, red tape, and state influence over the economy. Consequently, it may take some time for the expansion plans to materialize.

Iran has increased its domestic natural gas production fivefold over the past 20 years. Most of its natural gas production comes from the South Pars field, the largest natural gas field in the world, which Iran shares with Qatar. On Qatar's side, the field is called the *North Field*. Iran is developing 28 phases in South Pars, 10 of which are operational.[85] Phase 12 began production in early 2015 (3 Bcf/d of natural gas and 120,000 b/d of condensate). Production from phases 15 and 16 began at the end of 2015.[86] Between 2015 and 2020, Iran has the potential to add between 8 Bcf/d and 9 Bcf/d of new natural gas production, primarily from South Pars. The Kish field, the largest nonshared natural gas field in the country, is being developed. Kish has a production target of 0.9 Bcf/d of natural gas and 4 million barrels of gas condensate[87] per year, and $1.4 billion has been allocated for its development. In addition, after 2020, Iran plans to develop its North Pars, Golshan, and Ferdowsi natural gas fields.

In 2014, 93% of Iran's pipeline exports (0.9 Bcf/d) went to Turkey, and 0.03 Bcf/d went to Armenia and Azerbaijan (net of imports from Azerbaijan). Iran imported 0.7 Bcf/d from Turkmenistan in 2014, or half of its contractual volumes, as Iran's growing production allowed it to become more self-sufficient in delivering natural gas to its major consumption centers in the northern part of the country. The price of Iran's natural gas exports to Turkey is one of the highest in the region, and it has been used as a benchmark for Iran's other proposed pipeline export projects. However, the reluctance of Persian Gulf countries to sign contracts at those prices has been the main obstacle to Iran's development of new pipeline export projects. Future contracts for exports to Gulf countries are likely to require some reduction in the prices of Iranian natural gas exports.

Iran's Sixth Development Plan, which outlines its economic development goals for the next five years, sets a target to increase natural gas exports to more than 6 Bcf/d by March 2021. The target is based on expanding production primarily from the South Pars field, which can be exported by pipeline to Iran's neighboring countries. In the plan, Iran has prioritized pipeline exports over LNG exports, with a potential total of 3 Bcf/d to 4 Bcf/d in the next several years coming from projects that are close to completion.

*(continued on page 56)*

[81]C. Xu and L. Bell, "Global reserves, oil production show increases for 2014," *Oil & Gas Journal* (December 1, 2014).

[82]FACTS Global Energy, "Iran Oil & Gas Monthly Report" (Datafile) (London, UK: August 2015), https://www.fgenergy.com/ (subscription site).

[83]Reuters, "Fitch: Major Iranian Gas Exports Will Take at Least Five Years" (July 10, 2015), http://www.reuters.com/article/2015/07/10/idUSFit92836320150710#xjyCPxxARoAqX4sD.97.

[84]Domestic upgrades key to Iran exports," *World Gas Intelligence* (August 12, 2015), http://www.energyintel.com/pages/about_wgi.aspx (subscription site).

[85]Phase 11 of South Pars development was initially allocated to the Pars LNG project, with a production target of 1.9 Bcf/d of gas and 80,000 b/d condensate; however, because of sanctions, the project failed to progress.

[86]R. Yeganehshakib, "Will South Pars help bring Iran's economy back to life?" *Almonitor* (December 30, 2015), http://www.al-monitor.com/pulse/originals/2015/12/iran-south-pars-phases-15-16-inauguration-impact.html#.

[87]"Iran allocates $1.4 B to develop Kish gas field," *Natural Gas Europe: Greater Caspian Region Weekly Overview* (July 12, 2015), http://www.naturalgaseurope.com/greater-caspian-region-weekly-overview-july-12th-24609.

The focus of Iran's export pipelines is on neighboring Persian Gulf countries, Pakistan, potentially India, and in the longer term, exports to European countries via Turkey.

Exports of natural gas from Iran to the Persian Gulf countries—particularly, Iraq, Oman, Kuwait, and the United Arab Emirates (UAE)—are likely to begin by 2017–18.[88] There also are plans for Iran to increase exports to Iraq by 0.9 Bcf/d, to a total of 1.6 Bcf/d, but the duration of that export contract is expected to be short, because Iraq's domestic production increases in the mid-2020s. Iran is also planning pipeline exports to Oman (0.7 Bcf/d to 1.0 Bcf/d via a proposed 109-mile subsea pipeline); to Kuwait (0.3 Bcf/d to 0.5 Bcf/d); and to the UAE (0.6 Bcf/d to 1.5 Bcf/d). The existing pipeline network connecting Iran's Salman field to the Sharjah Emirate of the UAE can deliver 0.6 Bcf/d, but a dispute over the contract price has delayed gas shipments and is currently in international arbitration. If the pricing issue is resolved between parties, Iran can start exports to the UAE quickly.

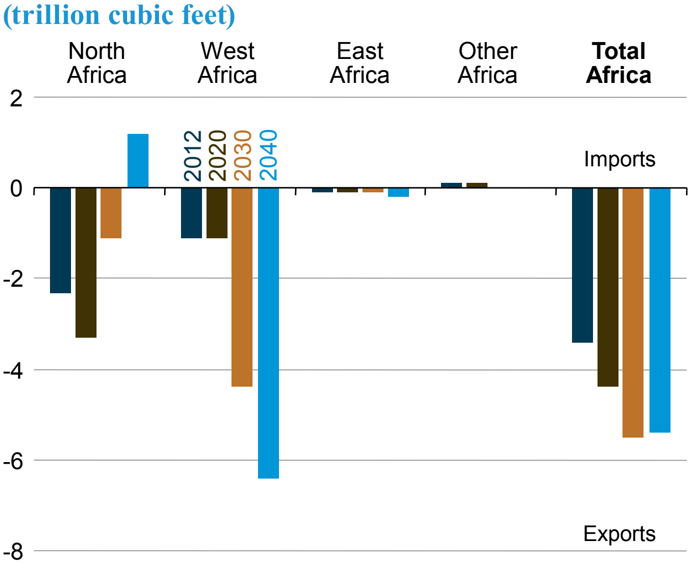
Proposed projects to export natural gas by pipeline from Iran to countries outside the Persian Gulf involve considerable risk for a variety of reasons. The proposed projects include:

- Pakistan plans to link the Iranian pipeline with a proposed $45 billion China-Pakistan Economic Corridor. Iran has built all but the final 155 miles on its side, and China is building a 435-mile stretch inside Pakistan that would move natural gas from Gwadar port in the West to Nawabshah in the South. The project requires building a short 50-mile leg to Gwadar from the border with Iran, which is likely to be financed by China. Risks include terrorist threats in Pakistan's Balochistan province, an enclave of Pakistani insurgents, and contract pricing that has not been finalized.
- Iran is in discussions to revive the Iran-Pakistan-India Peace Pipeline project, which may be a longer-term development. India has proposed to develop Iran's 12.8 Tcf Farzad-B natural gas field and is considering construction of subsea pipeline to link Iran directly with India. However, at an estimated cost of about $5 billion, the project is both expensive and technologically challenging.
- Iran also is considering exports to Europe via Turkey. An estimated $5.1 billion investment would be required to expand a 1,120-mile, 56-inch-diameter pipeline that would connect Assaluyeh with Bazargan near the Turkish border.

LNG exports from Iran may be a longer-term development. Iran will face strong competition, and its projects may not be economically viable in the current environment of low oil prices. Among the projects that have been proposed, the Iran LNG project (capacity 1.4 Bcf/d) may be the most likely to materialize after 2020. Iran has already spent $2.5 billion to build LNG port facilities, tank storage, and other infrastructure for the project and can now gain access to liquefaction technology not available when sanctions were in place. NIGC's announced target of increasing its natural gas liquefaction capacity to 10% of the world total by 2025 is not likely to be met.[89] However, some smaller projects—including delivering natural gas via pipeline to Oman to use spare capacity in the Qalhat LNG liquefaction project, and use of Das Island liquefaction facility in Abu Dhabi—are more likely to be developed in the next few years.

Elsewhere in the Middle East, Yemen, Oman, and Abu Dhabi of the United Arab Emirates (UAE) also are current exporters of LNG. However, the potential for growth in their exports and exports from other countries in the Middle East appears to be limited by their need to meet increases in their own domestic demand. The IEO2016 Reference case shows a similar trend for smaller producers in the Arabian Peninsula as a whole, including Kuwait, Oman, the UAE, and Yemen. As a group, they exported about 0.2 Tcf of natural gas on a net basis in 2012, and the volume of their net imports rises to a total of 1.2 Tcf in 2040.

**Figure 3-34. Africa net natural gas trade, 2012–40 (trillion cubic feet)**




### *Africa*

Net exports of natural gas from Africa increase in the IEO2016 Reference case by an average of 1.7%/year (Figure 3-34). In 2012, the region's net exports totaled about 3.4 Tcf, with 2.3 Tcf coming from North Africa. Net exports from West Africa grow at a robust average annual rate of 6.5% from 2012 to 2040, with much of the growth coming in the later part of the projection. Security concerns and uncertainty over terms of access in Nigeria have significantly delayed any progress on currently proposed LNG export projects.

Persistent, significant above-ground challenges in East Africa hamper export growth in that region. This is primarily owing to production and export proposals representing a large change in scale of operations for the oil and natural gas industries in Mozambique and Tanzania, where physical and regulatory infrastructures are not yet in place to support large-scale production and export of natural gas *(see "Potential for*

[88]"Iran's Gas Exports Outlook Post-Sanctions," *FACTS Global Energy*, Issue 238, published July 22, 2015 (subscription site), http://www.fgenergy.com.
[89]D.R. Jalilvand, *Iran's gas exports: can past failure become future success?* (Oxford, UK: June 2013), http://www.oxfordenergy.org/wpcms/wp-content/uploads/2013/06/NG-78.pdf.

*increased natural gas exports from Iran following the end of international sanctions," and "Liquefied natural gas: Growing use of floating storage and regasification units," above).*

### Non-OECD Asia

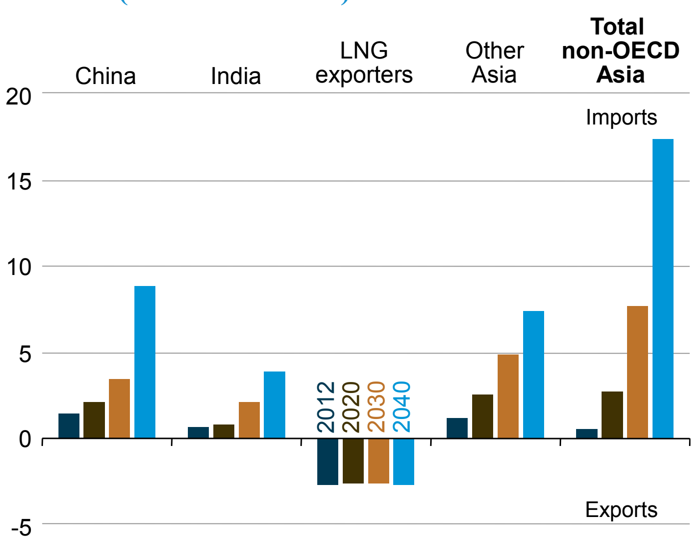
Non-OECD Asia has the highest regional growth rate in net imports of natural gas in the IEO2016 Reference case. With net imports of 17.5 Tcf in 2040, non-OECD Asia becomes the world's largest importing region, surpassing OECD Europe by 2040. China has the largest increase in import demand, to 8.9 Tcf/year in 2040, when nearly one-third of its annual natural gas consumption is supplied by imports (Figure 3-35).

To meet future demand, China is actively pursuing multiple potential sources for natural gas imports. Chinese companies have signed long-term agreements to deliver at least 6.6 Bcf/d through 2030.[90] Most of those contracts are with Asian firms sourcing LNG from Australia, Indonesia, Malaysia, Qatar, and Papua New Guinea. Moreover, there are additional contracts tied to new liquefaction projects located in Australia, Russia, and the United States that are scheduled to come online by 2020.

China is also pursuing multiple sources for pipeline natural gas imports, which have increased as production from Central Asia and Myanmar has grown and the non-OECD region's natural gas infrastructure has improved. China's total pipeline imports of natural gas exceeded its LNG imports in 2012, and in 2014 its LNG imports totaled 1.1 Tcf, up by 20% from 2013 LNG imports.[91] China's first natural gas import pipeline, which was completed in late 2009, now transports supplies from Turkmenistan and Uzbekistan. Another pipeline from Myanmar was completed in 2013, with the capacity to carry 0.4 Tcf/year of natural gas from Myanmar's offshore fields in the Bay of Bengal to Kunming in China's Yunnan province.[92] China also began importing natural gas from Kazakhstan in July 2013, but the quantities have been very small, constituting about 1% of the total pipeline imports into China in 2015.

In addition, Russia and China signed a significant natural gas agreement in May 2014. The deal was signed after a decade of negotiations over the import price and the supply route,[93] with China agreeing to purchase 1.3 Tcf of natural gas per year from Gazprom's East Siberian fields at a total cost of $400 billion over a 30-year period. The proposed Power of Siberia pipeline will connect Russia's eastern Siberian natural gas fields and Sakhalin Island to northeastern China. China's National Development and Reform Commission, which approved construction of the pipeline on the Chinese side in late 2014, anticipates that it will come online in 2018. In November 2014, Gazprom and the China National Petroleum Commission also signed a memorandum of understanding for China to import 1.1 Tcf/year from Russia's western Siberian natural gas fields, although many key details, including pricing details and required infrastructure expansion plans, have not yet been addressed.[94]

**Figure 3-35. Non-OECD Asia net natural gas trade, 2012–40 (trillion cubic feet)**




India has also increased its natural gas imports. Since 2013, unexpected production declines in India's Krishna Godavari basin have meant that the country must rely more heavily on LNG imports. As a result, Indian companies have invested in increasing the country's LNG regasification capacity in recent years to meet rising demand. In early 2013, GAIL (India's largest state-owned natural gas processing and distribution company), NTPC (India's largest power utility), and several other smaller players restarted the Dabhol project (originally proposed by the now-defunct Enron Corporation), which includes a regasification terminal to fuel three natural gas-fired power stations.[95] Dabhol LNG also ships natural gas to southern India through the new pipeline to Bengaluru. GAIL is installing a breakwater facility to double Dabhol's capacity by 2017. Petronet's LNG terminal at Kochi, commissioned in late 2013, is experiencing low utilization as a result of delays in the approval and construction of a proposed pipeline to Mangalore and other parts of southern India, according to IHS. India's natural gas imports grow in the IEO2016 Reference case by an average of 6.7%/year, to a total of 3.9 Tcf in 2040.

[90] Estimate derived from IHS Energy, "Liquefaction Sales Contract Database" (March 24, 2015), www.ihs.com (subscription site).

[91] U.S. Energy Information Administration, "China: International Energy Data and Analysis" (Washington, DC: May 14, 2015), https://www.eia.gov/beta/international/analysis.cfm?iso=CHN.

[92] Du Juan, "Myanmar-China gas pipeline opens," China Daily USA (July 30, 2013), http://usa.chinadaily.com.cn/epaper/2013-07/30/content_16851851.htm.

[93] E. Mazneva and S. Kravchenko, "Russia, China Sign $400B Gas Deal After Decade of Talks" *Bloomberg Business News* (May 21, 2014), http://www.bloomberg.com/news/articles/2014-05-21/russia-signs-china-gas-deal-after-decade-of-talks.

[94] J. Paton and A. Guo, "Russia, China Add to $400 Billion Gas Deal With Accord," *Bloomberg Business News* (November 9, 2014), http://www.bloomberg.com/news/articles/2014-11-10/russia-china-add-to-400-billion-gas-deal-with-accord.

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

### *Non-OECD Americas*

Natural gas trade in the non-OECD Americas region has become increasingly globalized as several countries have become involved in the LNG trade. In the IEO2016 Reference case, new LNG regasification capacity facilitates growth in the region's gross imports of natural gas through 2040, but the discovery of large new natural gas reserves throughout the region increases its gross exports by a larger amount. As a result, the region's overall trade balance remains relatively flat, with net exports increasing from 0.6 Tcf in 2012 to 0.7 Tcf in 2040 (Figure 3-36), after declining in the middle years of the projection.

Although LNG regasification facilities in Brazil and in the Southern Cone (excluding Chile, an OECD member state since 2010) have received LNG supplies fairly consistently over the past three years, the Southern Cone becomes a net exporter of natural gas by 2030 in the IEO2016 Reference case, largely as a result of the discovery of substantial shale gas reserves in Argentina's northwestern Neuquén province.[96] Net imports to Brazil remain essentially flat from 2012 through 2040. Overall net exports from the Andean region end in 2030 and net exports from the Northern Producers increase by an average of 0.5%/year from 2012 to 2040.

## World natural gas reserves

As reported by *Oil & Gas Journal*,[97] the world's proved natural gas reserves have grown by about 40% over the past 20 years, to a total of 6,950 Tcf as of January 1, 2016 (Figure 3-37). Estimated proved reserves in the non-OECD region as a whole have grown by 43% (1,912 Tcf) since 1996, while proved reserves in the OECD region have grown by 21% (104 Tcf) since 1996. As a result, the share of world proved natural gas reserves located in OECD countries has declined from 10% in 1996 to 9% in 2016.

The annual rate of growth in world proved natural gas reserves from 1980 to 1995 was notably higher than it has been in more recent years. Since 1995, the annual growth rate, while variable, has slowed to a reasonably steady rate of about 1.6%/year. Over the past 10 years, estimates of proved world natural gas reserves rose by 838 Tcf, or an average of 1.3%/year, as compared with 1,179 Tcf, or 2.2%/year on average over the previous 10 years (from 1996 to 2006). Estimated proved reserves in the non-OECD countries rose by 723 Tcf, or an average of 1.2% annually, over the past 10 years, compared with 2.4% annually from 1996 to 2006. The most rapid annual increase in non-OECD proved reserves in this period, at 12%/year, occurred from 2003 to 2004, supported by an increase in Qatar from 509 Tcf to 910 Tcf. In comparison, proved reserves in the OECD countries declined by 0.2%/year from 1996 to 2006 and increased by 115 Tcf, or an average of 2.1%/year, over the past 10 years.

World proved natural gas reserves generally have grown in each year since 1980, but declines have been reported for four years (1995, 1996, 2005, and 2015). Although world reserves increased by a modest 0.4% from 2015 to 2016, that increase follows a decrease of 1.5% (105 Tcf) from 2014 to 2015, and the estimate for 2016 still is lower than the 2014 level. Estimates of proved reserves in both the OECD and non-OECD regions show a similar trajectory; however, the absolute decrease in 2015 and the increase in 2016 were greater in the OECD countries, even though their reserve levels are less than one-tenth the levels in the non-OECD countries. Accordingly, the percentage decrease from 2014 to 2015 was 9.0% for the OECD countries, compared to 0.7% for the non-OECD countries, and the increase from 2015 to 2016 was 2.9% for the OECD countries, compared to 0.2% for the non-OECD countries.

**Figure 3-36. Non-OECD Americas net natural gas trade, 2012–40 (trillion cubic feet)**

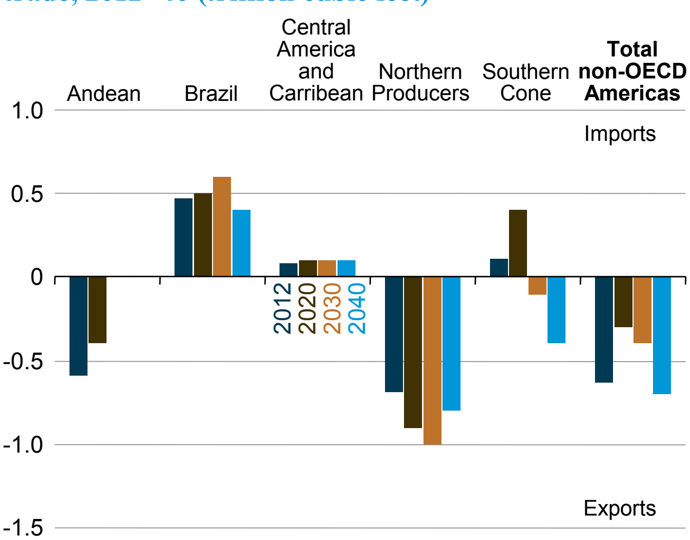
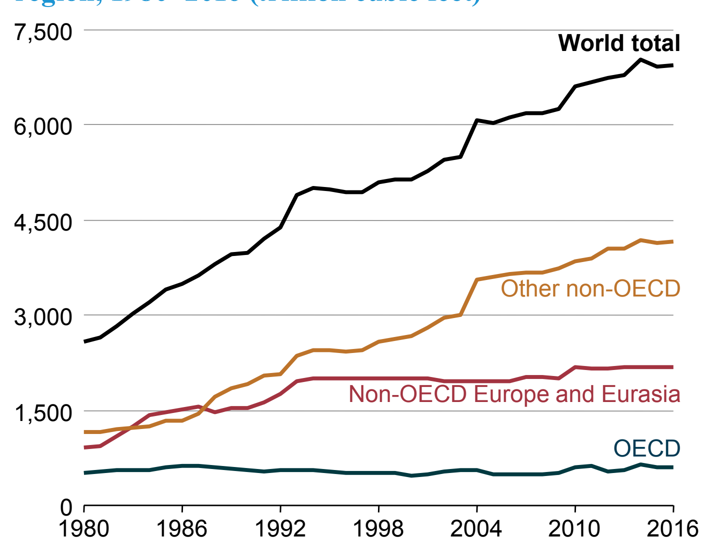



**Figure 3-37. World proved natural gas reserves by region, 1980–2016 (trillion cubic feet)**




[96]U.S. Energy Information Administration, "Argentina: International Energy Data and Analysis" (Washington, DC: April 2014), http://www.eia.gov/beta/international/analysis.cfm?iso=ARG.

[97]"Worldwide Look at Reserves and Production," *Oil & Gas Journal,* Vol. 113, No. 12 (December 7, 2015), pp. 22-23, http://www.ogj.com/articles/print/volume-113/issue-12.html (subscription site).

Estimates of world proved reserves increased by 31 Tcf from 2015 to 2016, with more than one-half of the increase (17 Tcf) coming from OECD countries. From 2015 to 2016, proved reserves in the OECD Americas rose by 29 Tcf, proved reserves in OECD Europe fell by 11 Tcf, and proved reserves in the countries of OECD Asia were nearly flat. Estimated proved reserves in the non-OECD countries increased by 13 Tcf from 2015 to 2016, with a combined 17 Tcf of additional proved reserves in China, Malaysia, India, and Angola partially offset by a decrease of 2 Tcf in Indonesia's proved reserves.

The largest change in proved natural gas reserve estimates was for the United States, where estimated proved natural gas reserves increased by 30 Tcf (9%), from 338 Tcf in 2015 to 369 Tcf in 2016. The second-largest change was for China, where estimated proved reserves increased by 11 Tcf (7%), from 164 Tcf in 2015 to 175 Tcf in 2016. As a result, China's estimated proved reserves are now the world's 10th largest, up from the 11th largest in 2015. The third-largest change in estimated proved reserves was for Saudi Arabia, with estimated reserve additions of 6 Tcf (2%), from 294 Tcf in 2015 to 300 Tcf in 2016. Although there were no changes in proved reserves for Russia and Iran, their proved reserves are ranked first and second in the world at 1,688 Tcf and 1,201 Tcf, respectively. Qatar and the United States are ranked third and fourth, at 866 Tcf (down 1%) and 369 Tcf (up 9%), respectively.

Current estimates of proved natural gas reserves worldwide indicate a large resource base to support growth in markets through 2040 and beyond. Like reserves for other fossil fuels, natural gas reserves are spread unevenly around the world. Natural gas proved reserves are concentrated in Eurasia and in the Middle East, where ratios of proved reserves to production suggest decades of resource availability. However, in the OECD countries, including many in which there are relatively high levels of consumption, current ratios of proved reserves to production are significantly lower. The impact of that disparity is reflected in the IEO2016 projections of increased international trade in natural gas.

Almost three-quarters of the world's proved natural gas reserves are located in the Middle East and Eurasia (Figure 3-38), with Russia, Iran, and Qatar together accounting for about 54% of world proved natural gas reserves as of January 1, 2016 (Table 3-2). Proved reserves in the rest of the world's regions are distributed fairly evenly. Despite high rates of increase in natural gas consumption, particularly over the past decade, most regional reserves-to-production ratios have remained high. Worldwide, the reserves-to-production ratio is estimated at 54 years. Central and South America has a reserves-to-production ratio of 44 years, Russia 56 years, and Africa 70 years. In contrast, the Middle East's reserves-to-production ratio exceeds 100 years.[98] The United States has a reserves-to-production (R/P) ratio of 13 years.[99]

**Figure 3-38. World proved natural gas reserves by region as of January 1, 2016 (trillion cubic feet)**

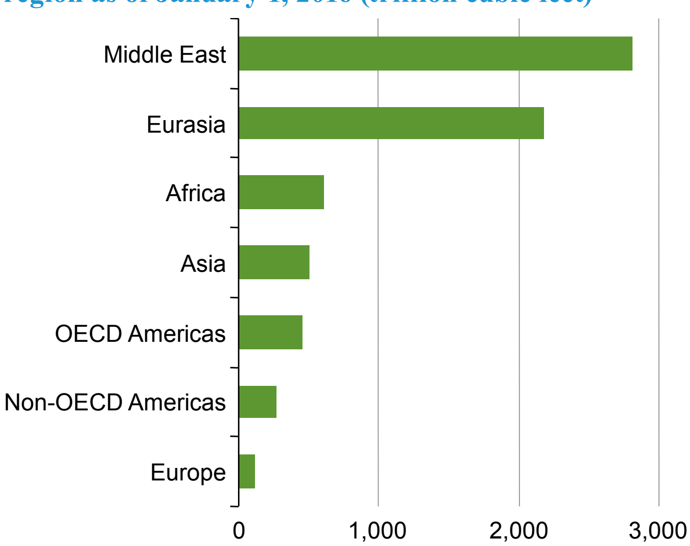



**Table 3-2. World natural gas reserves by country as of January 1, 2016**

| Country | Reserves (trillion cubic feet) | Percent of world total |
|---|---|---|
| World | **6,950** | **100.0** |
| Top 20 countries | **6,359** | **91.5** |
| Russia | 1,688 | 24.3 |
| Iran | 1,201 | 17.3 |
| Qatar | 866 | 12.5 |
| United States | 369 | 5.3 |
| Saudi Arabia | 300 | 4.3 |
| Turkmenistan | 265 | 3.8 |
| United Arab Emirates | 215 | 3.1 |
| Venezuela | 198 | 2.9 |
| Nigeria | 180 | 2.6 |
| China | 175 | 2.5 |
| Algeria | 159 | 2.3 |
| Iraq | 112 | 1.6 |
| Indonesia | 102 | 1.5 |
| Mozambique | 100 | 1.4 |
| Kazakhstan | 85 | 1.2 |
| Egypt | 77 | 1.1 |
| Canada | 70 | 1.0 |
| Norway | 68 | 1.0 |
| Uzbekistan | 65 | 0.9 |
| Kuwait | 63 | 0.9 |
| Rest of world | **591** | **8.5** |

[98] BP, "Natural gas: Total proved reserves," *BP Statistical Review of World Energy June 2015* (London, United Kingdom: June 2015), http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf.

[99] A 13-year R/P ratio does not imply that the United States will run out of gas in 13 years. The U.S. gas resource base is sufficiently large to allow for continuing expansion of both reserves and production (under most economic, technical, and environmental scenarios). It would not be unusual, for example, for an R/P ratio to remain constant or grow over time, despite production growth. Under R/P, the United States has had 10 years or so of natural gas remaining for the past 100 years. Clearly, the R/P ratio can be a misleading statistic.

Proved reserves include only estimated quantities of natural gas that can be produced economically from known reservoirs, and therefore they are only a subset of the entire potential natural gas resource base. Resource base estimates include estimated quantities of both discovered and undiscovered natural gas that have the potential to be classified as reserves at some time in the future. In the IEO2016 Reference case, the resource base does not pose a constraint on global natural gas supply. By basing long-term production assessments on resources rather than reserves, EIA is able to present projections that are physically achievable and can be supported beyond the 2040 projection horizon. The realization of such production levels depends on future growth in world demand, taking into consideration such above-ground limitations on production as profitability and specific national regulations, among others.

Chapter 4

# Coal

## Overview

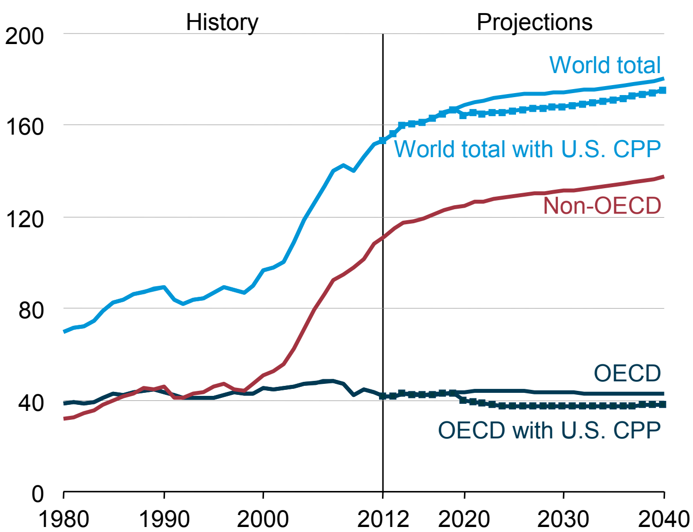
In the *International Energy Outlook 2016* (IEO2016) Reference case, coal remains the second-largest energy source worldwide—behind petroleum and other liquids—until 2030. From 2030 through 2040, it is the third-largest energy source, behind both liquid fuels and natural gas. World coal consumption increases from 2012 to 2040 at an average rate of 0.6%/year, from 153 quadrillion Btu in 2012 to 169 quadrillion Btu in 2020 and to 180 quadrillion Btu in 2040.

The Reference case estimates do not include the effect of the recently finalized Clean Power Plan (CPP) regulations in the United States, which would reduce world coal consumption to 165 quadrillion Btu in 2020 and to 176 quadrillion Btu in 2040 (about 2.5% in both years), based on EIA's analysis of the CPP proposed rule.[100] (EIA's analysis of the final rule is still being prepared; it is expected to show a roughly similar effect on projected coal use.) Over the 2012–40 projection period, total coal consumption in the non-OECD countries increases by an average of 0.8%/year, compared with an average increase of 0.1%/year in the OECD countries without the U.S. CPP and a decrease of 0.3%/year in the OECD countries with the U.S. CPP (Figure 4-1).

Throughout the projection, the top three coal-consuming countries are China, the United States, and India, which together account for more than 70% of world coal use. China accounted for 50% of world coal consumption in 2012, and its coal use continues to grow through 2025 in the Reference case before beginning a decline along with slower overall growth in energy consumption and the implementation of policies addressing air pollution and climate change. In 2040, China's share of world coal consumption falls to 46%. As a result of the slower growth and decline in China's coal use, the world coal share of total primary energy consumption declines steadily, from 28% in 2012 to 22% in 2040—in contrast to its sustained growth from 24% in 2001 to 29% in 2009, primarily as a result of increasing coal use in China. Total U.S. coal consumption per year, which peaked in 2007, remains largely unchanged from 2012 to 2040 without the CPP but declines significantly with the CPP. Although coal consumption in China does not change much from 2012 to 2040, coal use in India and the other countries of non-OECD Asia continues to rise. India's coal use surpasses the United States total around 2030, and its share of world coal consumption grows from 8% in 2012 to 14% in 2040 (Figure 4-2).

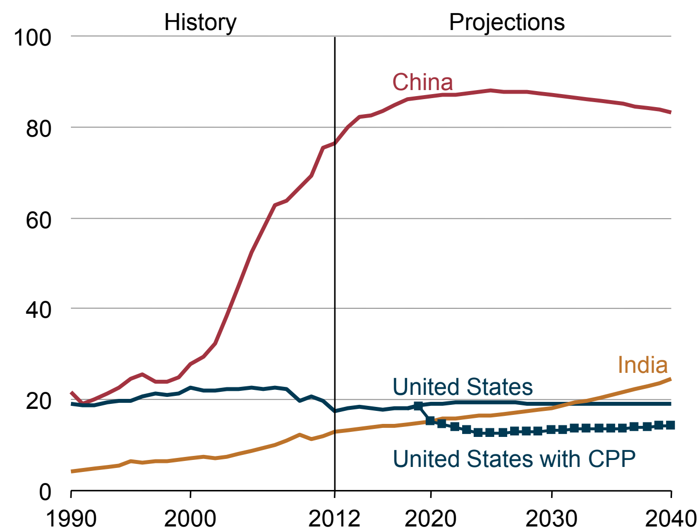
Electricity generation accounted for 59% of world coal consumption in 2012, and remains close to that share of coal use through 2040 in the IEO2016 Reference case (Figure 4-3). The industrial sector accounted for 36% of total coal use in 2012.[101, 102] Its share grows slightly in the Reference case, to 38% in 2040. Coal use in other sectors (residential and commercial), which made up 4% of total world coal consumption in 2012, accounts for 3% of the 2040 total. In the electric power sector, as renewable energy, natural

**Figure 4-1. World coal consumption by region, 1980–2040 (quadrillion Btu)**




Note: Dotted lines show projected effects of the U.S. Clean Power Plan.

**Figure 4-2. Coal consumption in China, the United States, and India, 1990–2040 (quadrillion Btu)**




Note: Dotted lines show projected effects of the U.S. Clean Power Plan.

[100] U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), https://www.eia.gov/analysis/requests/powerplants/cleanplan/.

[101] In IEO2016, the electric power sector includes only power plants that generate electricity or electricity and heat mainly for selling electricity to the electric grid. Unless otherwise noted, "electricity generators" refers to power plants in the electric power sector only, and "electricity generation" refers to electricity generated from those plants only. Coal consumed at plants that serve the electricity and heat needs of local industrial facilities is counted as industrial sector consumption.

[102] In this chapter, energy consumption expressed in percentage terms is calculated on the basis of energy content, and coal production expressed in percentage terms is calculated on the basis of physical tonnage.

gas, and nuclear power in combination account for a rising share of power generation. The share of electricity generated from coal worldwide declines from 40% in 2012 to 29% in 2040.

World coal production in the Reference case increases from 9 billion tons in 2012 to 10 billion tons in 2040,[103] with much of the growth occurring in India, China, and Australia (Figure 4-4). Their combined share of total world coal production increases in the IEO2016 Reference case from 60% in 2012 to 64% in 2040, but the share of the world's leading coal producer, China, decreases from 48% in 2012 to 44% in 2040. World coal production varies significantly from region to region in the Reference case, with sustained strong growth in India, slowing growth and a gradual decline after 2025 in China, and little change in the United States and OECD Europe.

Because most of the countries that consume substantial amounts of coal have domestic coal resources, the volume of world coal trade tends to be small relative to total consumption. On a tonnage basis, about 15% of the coal consumed worldwide in 2012 was imported. In the IEO2016 Reference case, the import share of world coal consumption declines slightly to 13% in 2020 and remains at that level through 2040. Total world coal trade also declines in the first few years of the projection, from 1,376 million short tons (MMst) in 2013 to 1,237 MMst in 2020, but increases thereafter to 1,354 MMst in 2040. The initial drop in world coal trade from 2013 to 2020 is attributable to projected declines in import demand for both China and India, where substantial expansion of domestic coal supplies reduces the need for imported coal. Coal trade increases from 2020 through 2040 but only to about its 2013 level. Increases in trade between 2020 and 2040 are attributable to additions of new coal-fired generating capacity, primarily in the countries of non-OECD Asia, and growing demand for imported coking coal in Asia.

International coal trade consists of two separate markets—one for steam coal (also referred to as thermal coal) and one for coking coal. Steam coal is used primarily for electricity generation and in industrial applications for the production of steam and direct heat. In the IEO2016 Reference case, international steam coal trade declines from 1,031 MMst in 2013 to 896 MMst in 2020, then increases to 960 MMst in 2040. Coking coal is used to produce coal coke, which in turn is used as a fuel and as a reducing agent for iron ore smelting in blast furnaces. World coking coal trade increases in the Reference case from 344 MMst in 2013 to 393 MMst in 2040. India, whose steel industry relies almost exclusively on imports of coking coal because of a lack of domestic reserves of coking coal, accounts for much of the growth, with its imports increasing from 43 MMst in 2013 to approximately 120 MMst in 2040.

## World coal consumption

### *OECD coal consumption*

With its total coal consumption remaining largely unchanged throughout the IEO2016 projection, the OECD share of world coal consumption shrinks as fuel market fundamentals and environmental regulations shift in favor of natural gas and renewables, particularly in the OECD Europe and OECD Americas regions. The United States is the largest coal consumer among the OECD countries, accounting for more than 40% of the OECD total from 2012 to 2040, and the decrease in its coal consumption from 2007 to 2012 led to a significant decline in total OECD coal consumption. In the Reference case, after a moderate recovery from 42 quadrillion Btu in 2012 to 44 quadrillion Btu in 2025, OECD coal consumption settles around 43 quadrillion Btu through 2040 (Figure 4-5), and the coal share of the OECD's total primary energy consumption falls from 18% in 2012 to 15% in 2040. Over the same period, the renewable energy (including hydropower) share of OECD energy use increases from 11% to 16%.

**Figure 4-3. Coal share of world energy consumption by sector, 2012, 2020, and 2040 (percent)**

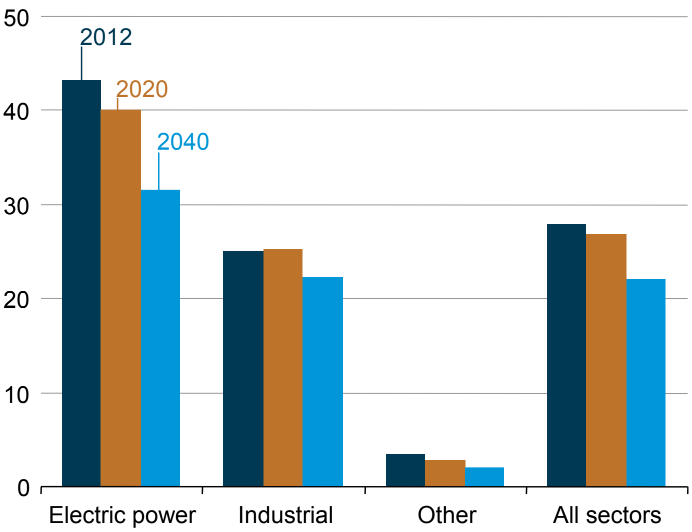
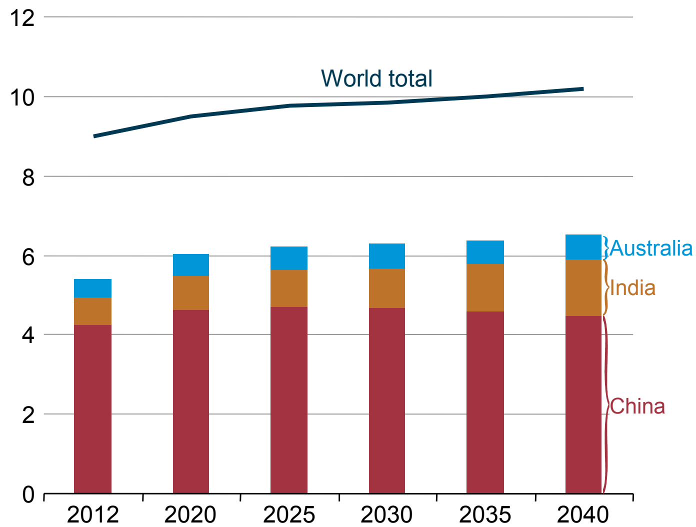



**Figure 4-4. World coal production, 2012–40 (billion short tons)**




[103]Throughout IEO2016, tons (of coal) refers to short tons (2,000 pounds) unless otherwise specified.

### *OECD Americas*

Most of the OECD Americas coal is consumed in the United States, which accounted for 93% the region's total coal use in 2012. In the IEO2016 Reference case, U.S. coal use remains relatively flat rising by only 2 quadrillion Btu over the projection period. However, if the proposed CPP were implemented, U.S. coal consumption decline by almost 3 quadrillion Btu by 2040 and U.S. coal consumption would be almost 25% lower in 2040 compared to the IEO2016 Reference case. Moreover, strong growth in shale gas production, slowing electricity demand, environmental regulations, and development of renewable energy reduce the share of coal-fired generation for total U.S. electricity generation (including electricity generated at plants in the industrial and commercial sectors) from 37% in 2012 to 26% in 2040 in EIA's analysis of the proposed CPP.[104]

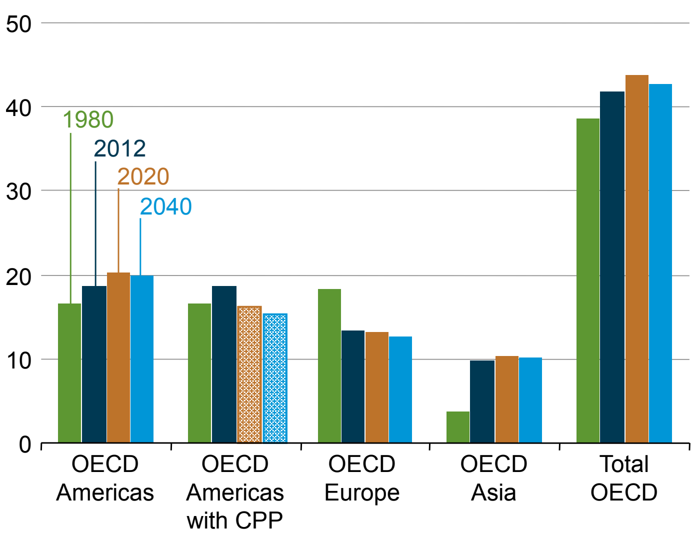
Coal plays a relatively minor role in Canada's energy supply system, and its role is expected to decline further with federal and provincial government efforts to reduce greenhouse gases. Canada's total coal consumption declines by 51% (0.4 quadrillion Btu) from 2012 to 2040 in the IEO2016 Reference case, and the share of coal in total primary energy supply declines from 5% in 2012 to 2% in 2040. In 2012, more than three-quarters of the coal consumed in Canada was used to generate electricity, with most of the rest going to industrial plants. The elimination of coal-fired generation in Ontario province in April 2014, followed by enactment of the Canadian government's "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity" regulations on July 1, 2015, is likely to result in more closures of coal-fired power plants.[105, 106] Consequently, in the Reference case, the electric power sector share of Canada's total coal consumption falls to 36% in 2040, and the coal share of total electricity generation declines from 10% in 2012 to 1% in 2040.

### *OECD Europe*

Total coal consumption in OECD Europe is largely flat in the Reference case, with a slight decline from 13.4 quadrillion Btu in 2012 (32% of the OECD total) to 12.6 quadrillion Btu in 2040 (30% of the OECD total). Although all nations in the region consume coal, 68% of OECD Europe's 2012 total coal consumption (in physical units) was concentrated in Germany, Poland, Turkey, and the United Kingdom. Germany alone accounted for 30% of the regional total. The electric power sector accounted for 70% of the region's total coal consumption in 2012, and the industrial sector accounted for most of the remainder.

With demand for coal declining in the electric power sector after 2025, the region's overall coal consumption also declines. The European Union's Industrial Emissions Directive, which requires the use of Best Available Technologies[107] for reduction of sulfur dioxide and nitrogen oxides among other pollutants beginning in 2016, is likely to trigger retirements of some coal-fired power plants, especially in the four leading coal-consuming countries.[108] However, new coal-fired capacity additions in Germany, Turkey, Poland, the Netherlands, and potentially Italy counterbalance the retirements. New coal-fired capacity in Germany fills a part of the supply gap left by a nuclear power phaseout; in Italy it replaces less competitive power plants (such as oil-to-coal conversions or replacement of older, less efficient units); in Turkey it supplies more power to meet demand growth.[109] After 2025, the expansion of renewable power and natural gas-fired generation leads to a gradual decline in coal-fired generation.

**Figure 4-5. OECD coal consumption by region, 1980, 2012, 2020, and 2040 (quadrillion Btu)**




### *OECD Asia*

Japan's coal consumption declines gradually through 2040 in the IEO2016 Reference case. Japan is the largest coal consumer in OECD Asia, accounting for nearly half (approximately 5 quadrillion Btu) of the region's total coal consumption in 2012. Coal use in Japan in 2012 was split almost evenly between the electric power and industrial sectors, which together accounted for nearly all of the region's coal consumption. Despite a temporary increase in coal use following the shutdown of nuclear power plants after the Fukushima disaster in 2011, a shift toward renewable energy and natural gas for electricity generation reduces electric power sector demand for coal after 2015. Industrial sector use of coal begins to decline after 2020, primarily as a result of reductions in steel output as Japan's population and domestic demand decline.

[104] U.S. Environmental Protection Agency, "Clean Power Plan for Existing Power Plants" (Washington, DC: November 20, 2015).

[105] Ontario Ministry of Energy, "Creating Cleaner Air in Ontario: Province Has Eliminated Coal-Fired Generation" (April 15, 2014), http://news.ontario.ca/mei/en/2014/04/creating-cleaner-air-in-ontario-1.html.

[106] Government of Canada, "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations" (August 30, 2012), http://www.gazette.gc.ca/rp-pr/p2/2012/2012-09-12/html/sor-dors167-eng.html.

[107] "Best Available Technologies" is defined as the latest stage of development ("state of the art") of processes, facilities, or methods of operation that indicate the practical suitability of a particular measure for limiting discharges.

[108] European Commission, "Prevention and control of industrial emissions," http://ec.europa.eu/environment/industry/stationary/.

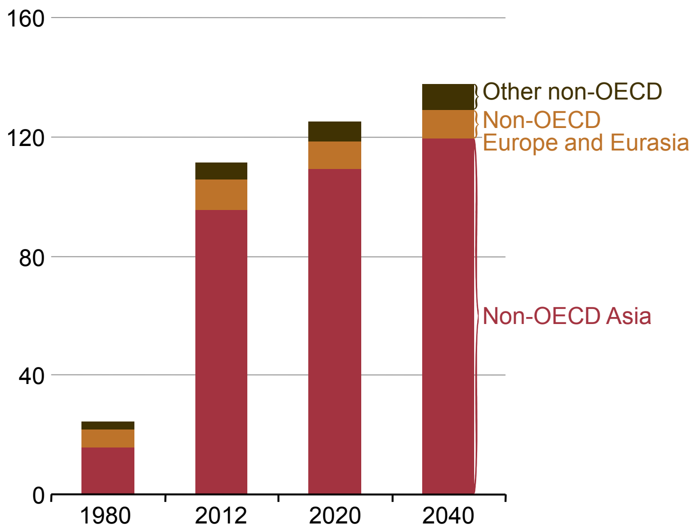
[109] IHS, "Global Steam Coal service: coal-fired power stations: operational and planned," https://connect.ihs.com/ (subscription site).

South Korea's coal consumption increases in the Reference case from 3 quadrillion Btu in 2012 to more than 4 quadrillion Btu in 2040. Coal consumption increases steadily in the country's industrial sector, driven by steel production. Coal consumption in the electric power sector, which accounted for 62% of total coal consumption in 2012, increases strongly in the near term, as a result of significant growth of the coal-fired generating fleet in response to the government's focus on thermal power expansion.[110] As nuclear and renewable power capacity continues to grow, coal consumption for electricity generation decreases in the medium term before recovering gradually after 2030 when the nuclear power expansion tapers off.

### *Non-OECD coal consumption*

In the IEO2016 Reference case, total non-OECD coal consumption increases by 0.8%/year on average, from 111 quadrillion Btu in 2012 to 137 quadrillion Btu in 2040 (Figure 4-6). Non-OECD Asia accounts for more than 90% of the growth in total non-OECD coal use over the projection. Coal is the largest source of energy consumed in the non-OECD region until around 2030, when the use of petroleum and other liquid fuels surpasses coal use.

**Figure 4-6. Non-OECD coal consumption by region, 1980, 2012, 2020, and 2040 (quadrillion Btu)**



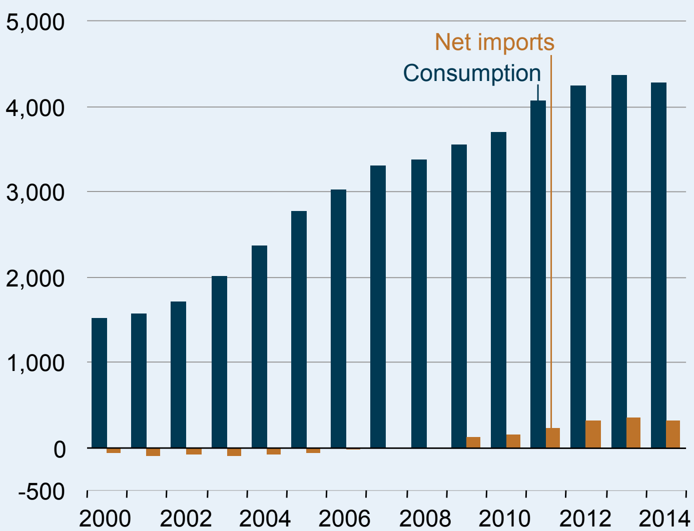

#### *Non-OECD Asia*

China and India are the top two coal consumers in non-OECD Asia. India, which is the second-largest coal user in the region, accounts for nearly one-half of the increase in coal consumption from 2012 to 2040, while China contributes less than one-third. China is the leading consumer of coal in the world, using 76 quadrillion Btu of coal in 2012—one-half of the world's coal consumption and more than four times as much as the United States, which was the world's second-largest coal consumer in 2012. In 2012, China's electricity-sector coal use alone was more than double total U.S. coal consumption, and China's industrial-sector coal use was nearly double total U.S. coal consumption. After rapid growth from 2003 to 2011, China's coal consumption began to slow in 2012. The slowing trend continues into the projection period, as the country's economy and energy system undergo structural changes *(see box below)*.

## Structural transformations in China's energy economy

Economic deceleration, industry restructuring, and new energy and environmental policies have slowed the growth of coal consumption in China, leading to more centralized and cleaner use of coal. Despite rapidly rising coal prices, China's coal consumption increased by an average of 9%/year (based on energy content) from 2003 to 2011. In 2012 and 2013, increases in coal consumption were between 1% and 2%. In 2014, coal consumption based on energy content was largely the same as in 2013 and coal consumption in physical units decreased for the first time since 1998,[111] as the average heat content of the coal consumed increased after years of decline. China's coal imports also declined in 2014 for the first time since 2009, when China became a net coal importer (Figure 4-7). The sustained slowing of coal consumption growth stands in contrast to the sustained falling of coal prices since 2012, which led to prices in 2014 that were 35% lower than prices in 2011 (Figure 4-8). The trends continued into 2015, signaling that fast-paced growth in China's coal use may not return, and suggesting that the pattern of growth in the China's coal consumption could be changing gradually (although not necessarily implying an imminent peak in coal consumption).

**Figure 4-7. China coal consumption and net imports, 2000–2014 (million short tons)**




*(continued on page 65)*

[110]Ministry of Knowledge Economy, "The 6th basic plan of long-term electricity supply and demand (2013-2027)" (February 2013), www.kpx.or.kr/eng/downloadBbsFile.do?atchmnflNo=23330.

[111]U.S. Energy Information Administration, "Recent statistical revisions suggest higher historical coal consumption in China," *Today In Energy* (Washington, DC: September 16, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=22952&src=email.

Slower growth of gross domestic production (GDP) and shifts in GDP composition have slowed the growth of China's total energy consumption. In 2014, for the first time in 15 years, China did not meet or exceed its economic growth targets. Real GDP grew by 7.4%, below the 7.5% target the government set in March 2014 for the year and economic growth rates over the prior decade. For many years, China pursued high GDP growth through massive investments in energy-intensive industrial development, coupled with targeted monetary policy. The recent economic slowdown was in part a result of diminishing returns on investment, financial sector problems, and inefficiencies at state-owned enterprises, among other factors. Currently, the government is exploring ways to address those issues through deeper, market-oriented reforms; polices intended to accelerate the development of the service sector and to increase domestic consumption; and setting goals and implementing regulations to balance economic growth with environmental protection.

Changes in the composition of China's economy, with shifts toward the less energy-intensive service sector, also are affecting energy consumption. In 2013, the service sector share of nominal GDP (46.9%) surpassed the industry sector share (43.7%) for the first time in China's history. In 2014, the service sector share increased to 48.2%, exceeding the government's goal of 47% for 2015 (Figure 4-9). The government's ongoing policy push to accelerate the development of service industries,[112] as well as the history of developed economies, suggests that the service sector share of China's GDP will continue to increase in the long run, at the expense of the heavy manufacturing industries. This trend should moderate or reduce coal consumption.

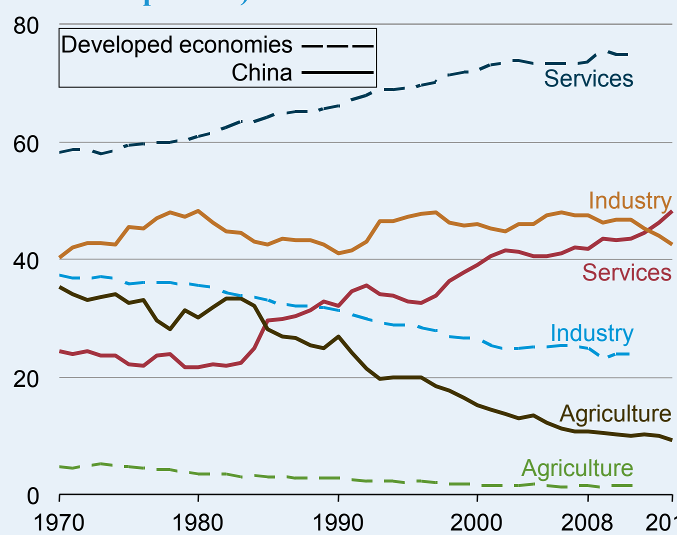
In addition to the effects of slower economic growth and GDP composition changes on China's coal use, industry restructuring has slowed the growth of coal-intensive industries such as steel, cement, and fertilizer and increased the average energy efficiency of industrial processes (Figure 4-10). Direct coal burning in the industrial sector accounted for about 20% of China's coal consumption in 2012, compared with less than 5% in the United States. The Made in China 2025 blueprint unveiled by the State Council in May 2015[113] outlined an action plan to modernize China's manufacturing through innovation enhancements and the integration of information technology into manufacturing, while continuing to make efficiency improvements and shedding excess and outdated heavy manufacturing capacity. If successfully implemented, the plan could accelerate not only the reduction in the manufacturing sector's energy intensity but also the transformation of its energy consumption patterns. Coal use would be concentrated increasingly in large and more efficient energy conversion facilities (mainly, power and heat generation plants), as hundreds of thousands of scattered, inefficient, and highly polluting small coal-fired boilers are phased out.

*(continued on page 66)*

**Figure 4-8. China coal prices, 2004–14 (nominal renminbi per short ton)**


Notes: Price shown are annual spot prices for Datong 5,800 kcal/kg net as received, free on board Qinhuangdao, reported by IHS China Energy Services. The renminbi is the official currency of the People's Republic of China.

**Figure 4-9. Economic composition of gross domestic product in China and developed economies by sector, 1970–2014 (value-added percent of nominal gross domestic product)**




Notes: The "developed economies" are as defined in United Nations Conference on Trade and Development, "Development status groupings and composition" (July 3, 2015), http://unctadstat.unctad.org/EN/Classifications/DimCountries_DevelopmentStatus_Hierarchy.pdf. "Industry" here refers to an economic sector and is different from the IEO2016 "industrial sector," which includes agriculture.

[112]National Development and Reform Commission, "China's Policies and Actions on Climate Change" (November 2014), http://en.ccchina.gov.cn/archiver/ccchinaen/UpFile/Files/Default/20141126133727751798.pdf.

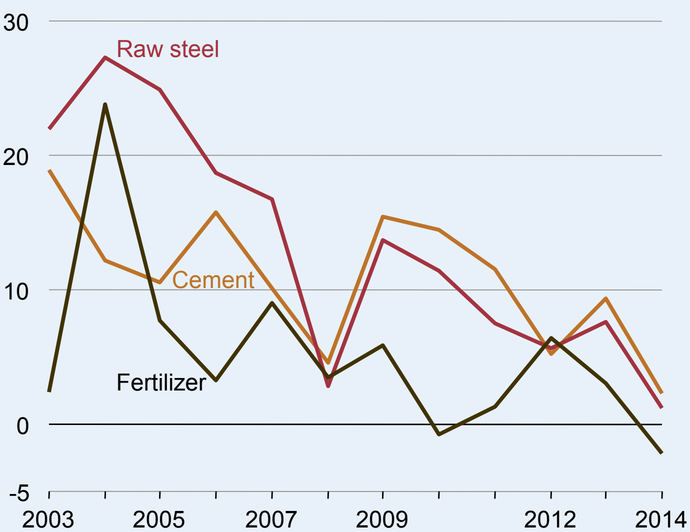
[113]The State Council, People's Republic of China, "'Made in China 2025' plan issued" (May 19, 2015,), http://english.gov.cn/policies/latest_releases/2015/05/19/content_281475110703534.htm.

China's energy policy focus has evolved from energy supply security to sustainability, calling for controlled, cleaner, and more efficient use of coal. Concerted new policies and regulations[114] galvanized by severe air pollution in 2013 and 2014 started a widespread campaign of upgrading the coal fleet nationwide, restricting coal use in coastal China, reducing coal consumption in targeted industries, and expediting the expansion of alternative energy sources. The coal share of China's energy consumption is expected to continue declining if the following goals are implemented successfully:

- The 2014-2020 Action Plan for Upgrading and Transforming Energy Conservation and Emission Reduction in Coal Power Industry,[115] issued jointly by China's National Development and Reform Commission (NDRC), Ministry of Environmental Protection, and National Energy Administration, sets strict, detailed standards on the size, technology, efficiency, and emissions of existing and new coal-fired power plants and requires the adoption of advanced coal technologies. Compliance with the standards will increase the average efficiency of China's fleet of coal-fired power plants, reduce coal consumption for every unit of electricity generated, and slow the rate of growth in demand for coal from the power sector compared with the growth rate of coal-fired power generation.
- An action plan[116] jointly announced by China's Ministry of Industry and Information Technology and the Ministry of Finance aims to cut coal consumption in coking and coal-to-chemicals processes, industrial boilers, and industrial kilns by more than 80 million metric tons by 2017 and by more than 160 million tons by 2020.[117]
- The Energy Development Strategy Action Plan (2014-2020),[118] released by the State Council immediately after the China-U.S. Joint Announcement on Climate Change,[119] set binding caps on annual primary energy and coal consumption until 2020 at absolute levels for the first time. It also specified targets for reducing the coal share of primary energy consumption to less than 62% and increasing the share of nonfossil energy to 15% by 2020 and to about 20% by 2030. Specific targets for reducing coal consumption in key eastern regions and specific development targets for natural gas, nuclear, hydropower, wind, and solar power capacity builds are assigned accordingly.

In addition, China's government leaders have taken actions to strengthen implementation of environmental policies and regulations. The revised Environmental Law[120] included provisions to add fulfillment of environmental targets to the performance assessment of governmental officials, raised both organizational and personal liabilities for noncompliance, enhanced emissions monitoring, increased public disclosure of environmental information, and provided protection for whistleblowers. Although many details remain to be developed and many controversies need to be resolved, passage of the law after three years of contentious debate suggests the central government's increasing commitment to more sustainable development.

**Figure 4-10. Annual changes in production from China's coal-intensive industries, 2003–14 (percent)**




The moderating growth of the total energy consumption and the shrinking coal share suggest that China's coal consumption could stay on the path of slow grow followed by decline. However, the sheer size of the country's additional future energy demand even with weaker economic growth, plus coal's dominance and economic appeal, indicate that coal will remain the leading energy source in China for many years to come. Therefore, while seeking to limit coal consumption on one hand, the Chinese government has also focused on consolidating and modernizing the domestic coal mining industry,[121] mitigating the environmental effects of

*(continued on page 67)*

[114]China Council for International Cooperation on Environment and Development (CCICED), *Progress in Environment and Development Policies in China (2013-2014) and CCICED Policy Recommendations Impact* (December 2014), http://www.cciced.net/encciced/policyresearch/impact/201504/P020150413373426638425.pdf.

[115](Chinese) Ministry of Environmental Protection (September 2014), http://www.mep.gov.cn/gkml/hbb/gwy/201409/W020140925407622627853.pdf.

[116]China Energy Conservation and Environmental Protection Group, "Three Ministries and Commissions Jointly Issue Action Plan for the Transformation and Upgrading of Coal Power Energy Conservation and Emission Reduction" (October 9, 2014), http://www.cecep.cn/g3621/s12528/t37687.aspx.

[117]Xinhua Finance Agency, "China targets industrial coal use for environmental protection" (March 2, 2015), http://en.xinfinance.com/html/Industries/Energy/2015/59603.shtml.

[118]Xinhuanet, "China unveils energy strategy, targets for 2020" (November 19, 2014), http://news.xinhuanet.com/english/china/2014-11/19/c_133801014.htm.

[119]L. Lan, "China, US promise to reduce emissions," China Daily (November 13, 2014), http://m.chinadaily.com.cn/en/2014-11/13/content_18904652.htm.

[120]"China's harsher environmental protection law to take effect," *China Daily* (January 1, 2015), http://www.chinadaily.com.cn/business/2015-01/01/content_19212213.htm.

[121](Chinese) Coal Industry Policy, National Energy Administration, February 2013, http://www.nea.gov.cn/2013-02/04/c_132149959.htm.

coal mining, and improving the logistics of coal supply[122] to ensure the steady operation and continued development of the country's coal sector and to improve the economic competitiveness of domestic coal relative to imports.

Coal consumption in China reaches a peak of nearly 90 quadrillion Btu around 2025 before gradually declining to 83 quadrillion Btu in 2040 (Figure 4-11). Government policy and an economic slowdown are responsible for the peak and ultimate decline in China's coal consumption. For many years, reducing energy intensity has been a part of the government's five-year plans. In the IEO2016 Reference case, total energy consumption growth slows to less than 2%/year from 2012 to 2040, compared to nearly 10%/year from 2003 to 2011.

China's economic growth averages 4.7%/year from 2012 to 2040, while the economy gradually transitions away from heavy manufacturing to less energy-intensive service industries. In addition, the government continues to pursue policies aimed at improving energy efficiency by setting binding industry-specific targets and monitoring implementation. Consistent with President Xi's 2014 pledge to stop CO2 emissions from increasing by around 2030, the central government has declared ambitious goals and provided incentives to expedite the development of nuclear and renewable power, and to replace coal with natural gas in some eastern regions. In the IEO2016 Reference case, natural gas, renewables (including hydroelectric power), and nuclear power together provide more than 70% of the increment in China's total primary energy needs from 2012 to 2040. Natural gas, renewables, and nuclear, which in combination accounted for less than 25% of China's total electricity generation in 2012, account for 55% of the total in 2040. As a result, the coal share of China's electricity generation declines from about 75% in 2012 to 45% in 2040, and the coal share of China's total primary energy consumption declines from 66% in 2012 to 44% in 2040 (Figure 4-12).

India, the world's third-largest coal consumer in 2012, is projected to surpass the United States as the second-largest coal consumer. Coal consumption in India increases from 13 quadrillion Btu in 2012 to 25 quadrillion Btu in 2040. Coal is especially important to India's electric power generation, and 63% of its total coal consumption in 2012 was for generation. India's rapid economic growth (average GDP growth of 5.5%/year from 2012 to 2040), combined with its growing population (average population growth of 0.8%/year from 2012 to 2040), leads to electricity demand growth of 3.5%/year in the IEO2016 Reference case. India's population surpasses China's in the late 2020s, with an expanding middle class using more electricity-consuming appliances. Coal-fired generation accounted for 72% of India's total electricity generation in 2012 and is expected to increase by 2.6%/year over the projection, as the country strives to provide enough electricity to meet growing demand. India's net coal-fired electricity generation grows by 783 terawatthours, which is more than the 2012 total; and its coal consumption for electricity generation nearly doubles, from 8 quadrillion Btu in 2012 to 15 quadrillion Btu in 2040.

Outside of China and India, coal consumption in the other nations of non-OECD Asia grows by an average of 2.3%/year in the Reference case, from 6 quadrillion Btu in 2012 to 11 quadrillion Btu in 2040. More than two-thirds of the additional coal consumed is for electricity generation. Indonesia, Malaysia, Taiwan, Vietnam, and Thailand were the major contributors to coal consumption growth in the other non-OECD Asia countries from 2000 to 2013, with Malaysia's coal demand growing at the fastest pace.[123] Favorable economics of coal-fired generation over natural gas-fired generation in Southeast Asia have sparked growth of coal-fired generating capacity in the region in the past decade, and significant additional capacity is already in the pipeline, particularly

**Figure 4-11. Coal consumption in the United States and China and in China's electric power and industrial sectors, 2012, 2020, and 2040 (quadrillion Btu)**

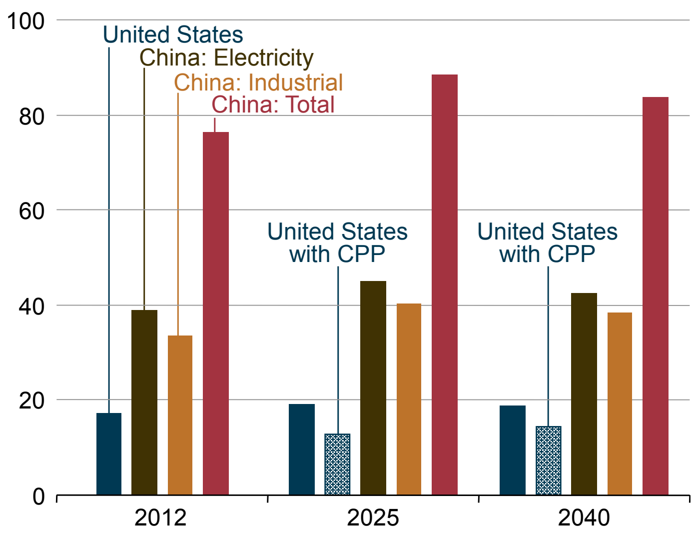
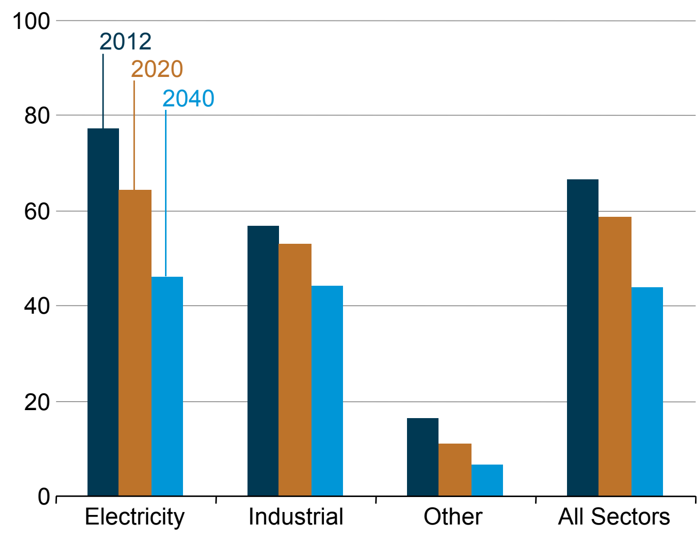



**Figure 4-12. Coal share of China's energy consumption by sector, 2012, 2020, and 2040 (percent of total)**




[122](Chinese) Coal Logistics Development Plan, National Development and Reform Commission (December 2013), http://www.sdpc.gov.cn/zcfb/zcfbghwb/201401/W020140221373227123903.pdf.

[123]U.S. Energy Information Administration, International Energy Statistics, http://www.eia.gov/beta/international/.

in Vietnam, Malaysia, Indonesia, and Taiwan. In the IEO2016 Reference case, coal-fired generating capacity in non-OECD Asia (excluding China and India) nearly doubles from 2012 to 2040.

### *Non-OECD Europe and Eurasia*

In 2012, coal accounted for 20% of the total primary energy supply in non-OECD Europe and Eurasia, where natural gas use is more prevalent than other energy sources. Russia consumes more than half of the region's coal throughout the projection period, although coal provides only 16% to 17% of Russia's primary energy needs. Coal consumption in Russia increases slightly in the IEO2016 Reference case, whereas total coal consumption by the other countries in the region shows little change.

Russia's electric power and industrial sectors each consumed about the same amount of coal in 2012, and together they accounted for 90% of Russia's total coal consumption. The residential and commercial sectors used the remaining 10%—exceeding the world average share of 4% in 2012—primarily for space heating and water heating. Coal-fired generation, which accounted for only 16% of Russia's total electricity generation in 2012, declines further before 2025 as a result of increasing nuclear power generation and a short-term, temporary reduction in total electricity demand resulting from the effects of international financial sanctions imposed on Russia in 2014. After 2025, coal use in the electricity sector recovers as electricity demand grows and generation from nuclear power plants decreases. Coal use in the industrial sector declines as a result of the 2014 sanctions but recovers to slightly above the pre-sanction levels toward the end of the projection.

### *Africa*

In the IEO2016 Reference case, total coal consumption in Africa increases from just under 5 quadrillion Btu in 2012 to 7 quadrillion Btu in 2040, mainly as a result of demand in the electric power sector and metallurgical industries. South Africa accounts for more than 90% of Africa's total coal consumption and more than 72% of its total primary energy consumption in 2012.[124] More than one-half of the coal consumed in South Africa is for electricity generation, one-third is for coal-to-liquids (CTL) production, and most of the remainder is for metallurgical use.[125] (CTL and metallurgical coal use are classified as industrial sector uses in IEO2016.) More than 85% of South Africa's installed electric generating capacity is powered by coal,[126] and although the government prefers a diversified generation portfolio with more renewable power,[127] chronic power shortages combined with the economic advantage of coal-fired generation suggest that coal will continue growing as a primary source of energy supply for South Africa.

## World coal production

In the IEO2016 Reference case, world coal production increases by 1.2 billion tons from 2012 to 2040, with 0.7 billion tons (62% of the total increase) coming from India (Table 4-1). China remains the largest coal producer through 2040, although its annual production declines in the second half of the projection period after peaking at approximately 4.7 billion tons in 2025. Production in Australia, Africa, and Russia also increases substantially, with their combined increases representing 24% of the world's total production increase. As shown in Table 4-1, coal production in the United States and OECD Americas, as a whole is significantly reduced by the proposed U.S. Clean Power Plan. The actual effect of the CPP on U.S. coal production is likely to be sensitive to implementation decisions, and would tend to be larger than shown if states choose a mass-based implementation strategy.

Coal production trends in China and India hinge on their ability to meet domestic coal demand. China is expected to supply coal primarily from domestic sources through 2040, given the magnitude of its current coal consumption requirements and production capacity, its increasing reliance on newer, large coal mining bases that are farther from coastal export terminals, and its efforts to improve the competitiveness of its domestic coal production. India's sustained and accelerating domestic demand for coal throughout the projection period requires significant expansion of domestic production. A host of government policies, regulatory efforts, and investment activities are moving in the direction of enabling this long-awaited expansion *(see box below)*. In the IEO2016 Reference case, India's coal production expands strongly from 2015 to 2020 and eventually surpasses U.S. coal production, making India the world's second-largest coal producer.

## India's coal supply chain: Challenges and reforms

India is the world's third-largest coal producer, with about 600 million metric tons (MMmt) of production in fiscal year 2013–14[128] falling behind the United States (900 MMmt in 2013) and China (about 4,000 MMmt in 2013). From 2005 to 2012, the total capacity of India's fleet of coal-fired power plants, already underutilized as a result of coal shortages, grew by about 9.4%/year while its coal production grew by only 4.7%/year (Figure 4-13). As a result of the imbalance between coal supply and demand, India frequently has resorted to forced outages of coal-fired generating plants, lower plant utilization rates, and increased coal imports. To end its coal supply shortfall, India has set an ambitious coal production target of 1.5 billion metric tons by 2020. Success in meeting that goal will depend heavily on the timing and effectiveness of reforms in the country's strained coal supply chain.

*(continued on page 69)*

[124]BP, Statistical Review 2015, http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.
[125]Eskom, "Coal in South Africa," http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/CO_0007CoalSARev13.pdf.
[126]U.S. Energy Information Administration, "South Africa" (April, 2015), http://www.eia.gov/beta/international/analysis.cfm?iso=ZAF.
[127]U.S. Energy Information Administration, "South Africa" (April, 2015), http://www.eia.gov/beta/international/analysis.cfm?iso=ZAF.
[128]India production, 2013-14: Government of India, Ministry of Coal, *Provisional Coal Statistics 2013-14* (Kolkata, July 2014), Table 2.9, "Trends of Company Wise Production of Coal & Lignite During Last Three Years," http://www.coal.nic.in/sites/upload_files/coal/files/coalupload/provisional1314_0.pdf.

### Coal production challenges

India's ambitious goal of 1,500 MMmt total annual coal production by 2020 includes 1,000 MMmt from its national coal producer, Coal India Ltd. (CIL). To attain this level, CIL's annual coal production alone must increase by more than 400 MMmt within 5 years; previously, it took the country more than 20 years to ramp up to such an increase in coal production. From 2002 to 2012, India's total coal production grew by 25 MMmt per year on average, with a peak annual increase of 45 MMmt in 2009. As of February 2015, CIL has identified coal projects capable of producing about 900 MMmt per year by FY2019–20.[129]

Despite coal distribution reforms, CIL continues to face challenges. Before 2008, CIL linkages (guarantees of certain levels of coal supply provided at a fixed price to coal consumers) were assigned in a discretionary manner by two CIL committees, and linkage recipients were not legally allowed to resell their coal. Beginning in 2007, CIL introduced a revised coal distribution policy that replaced linkages with auctions and fuel supply agreements (FSAs). FSAs allow a more transparent process by which coal consumers can negotiate guaranteed coal supplies under take-or-pay arrangements.

*(continued on page 70)*

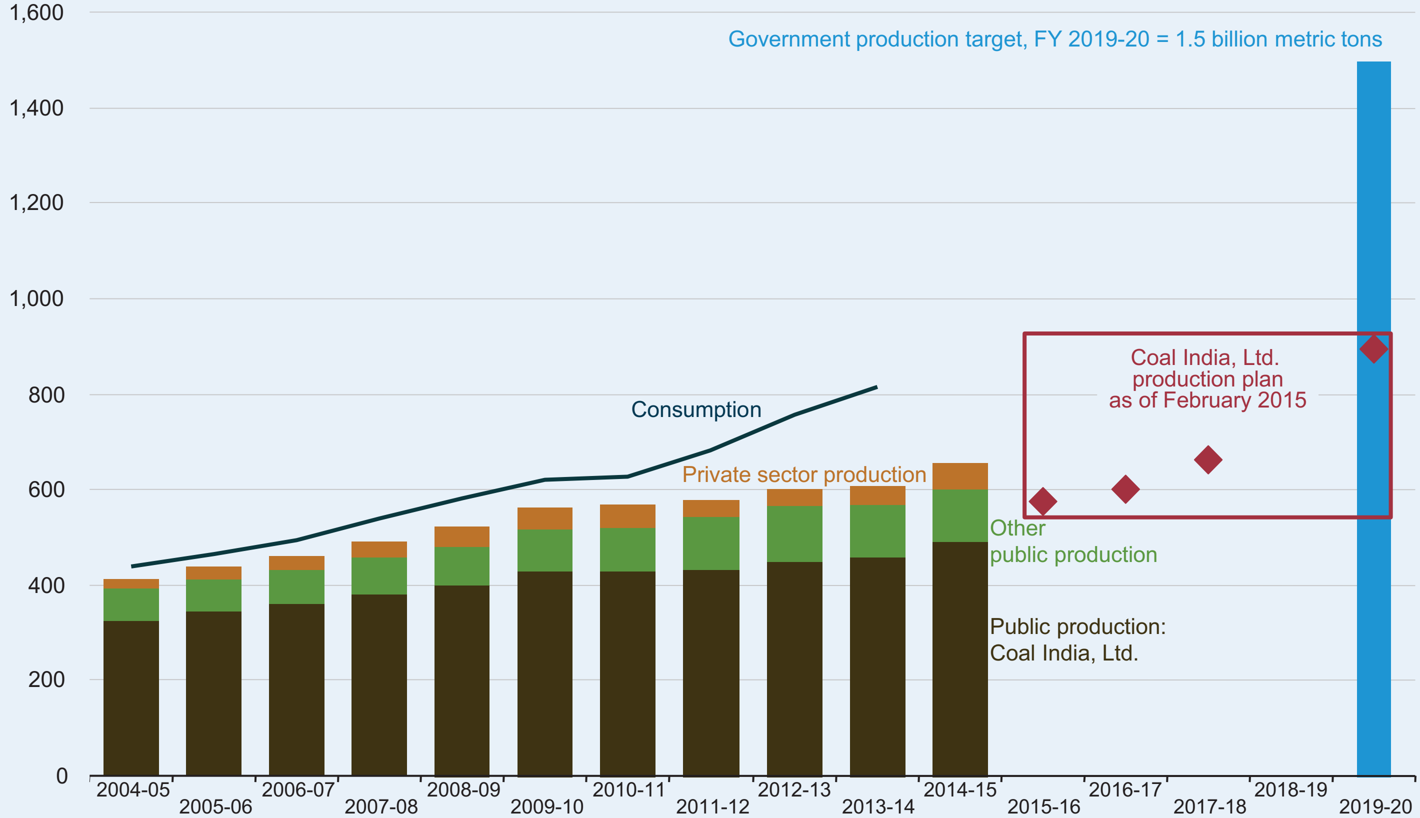
### Table 4-1. World coal production by region, 2012–40 (million short tons)

| Region/Country | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| **OECD** | **2,237** | **2,341** | **2,396** | **2,366** | **2,356** | **2,351** | **0.2** |
| **OECD with CPP** | **2,237** | **2,150** | **2,092** | **2,124** | **2,154** | **2,223** | **0.0** |
| **OECD Americas** | **1,107** | **1,125** | **1,143** | **1,122** | **1,122** | **1,096** | **0.0** |
| OECD Americas with CPP | 1,107 | 934 | 839 | 880 | 920 | 968 | -0.5 |
| United States | 1,016 | 1,044 | 1,060 | 1,048 | 1,045 | 1,020 | 0.0 |
| United States with CPP | 1,016 | 853 | 756 | 806 | 843 | 892 | -0.5 |
| Canada | 73 | 67 | 70 | 60 | 63 | 61 | -0.6 |
| Mexico/Chile | 17 | 14 | 13 | 13 | 14 | 15 | -0.5 |
| **OECD Europe** | **630** | **647** | **663** | **650** | **642** | **641** | **0.1** |
| **OECD Asia** | **501** | **569** | **591** | **594** | **593** | **614** | **0.7** |
| Japan | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| South Korea | 2 | 2 | 2 | 2 | 2 | 1 | -2.2 |
| Australia/New Zealand | 498 | 567 | 589 | 592 | 591 | 613 | 0.7 |
| **Non-OECD** | **6,741** | **7,142** | **7,353** | **7,459** | **7,623** | **7,825** | **0.5** |
| **Non-OECD Europe and Eurasia** | **750** | **711** | **721** | **737** | **742** | **730** | **-0.1** |
| Russia | 392 | 435 | 444 | 459 | 465 | 452 | 0.5 |
| Other | 358 | 276 | 278 | 278 | 278 | 277 | -0.9 |
| Non-OECD Asia | 5,584 | 5,986 | 6,164 | 6,242 | 6,379 | 6,552 | 0.6 |
| China | 4,256 | 4,621 | 4,706 | 4,670 | 4,598 | 4,494 | 0.2 |
| India | 666 | 841 | 921 | 1,014 | 1,185 | 1,408 | 2.7 |
| Other | 663 | 524 | 537 | 558 | 597 | 650 | -0.1 |
| **Middle East** | **1** | **1** | **1** | **1** | **1** | **1** | **0.3** |
| **Africa** | **296** | **330** | **353** | **366** | **381** | **413** | **1.2** |
| **Non-OECD Americas** | **110** | **114** | **114** | **113** | **120** | **129** | **0.6** |
| Brazil | 7 | 6 | 6 | 7 | 7 | 8 | 0.1 |
| Other | 103 | 107 | 107 | 106 | 113 | 122 | 0.6 |
| **Total World** | **8,978** | **9,483** | **9,750** | **9,825** | **9,980** | **10,176** | **0.4** |
| **Total World with CPP** | **8,978** | **9,292** | **9,446** | **9,583** | **9,778** | **10,048** | **0.4** |

Note: With the exception of North America, non-seaborne coal trade is not represented in EIA's forecast scenarios. As a result, the projected levels of production assume that net non-seaborne coal trade will balance out across the IEO2016 regions. Currently, a significant amount of non-seaborne coal trade takes place in Eurasia, represented by exports of steam coal from Kazakhstan to Russia and exports of coking coal from Russia to Ukraine.

[129] S. Jha, "Coal India goes for makeover," *The Financial Express* (June 3, 2015), http://www.financialexpress.com/article/industry/companies/coal-india-goes-for-makeover/79443/; and "Coal India gearing up for 1 billion tonne coal production," Newsroom24x7 (February 20, 2015), http://newsroom24x7.com/2015/02/20/coal-india-gearing-up-for-1-billion-tonne-coal-production/.

**Figure 4-13. India's domestic coal consumption, production, and production targets by fiscal year, 2004–20 (million metric tons)**




Even with the ongoing challenges, India's coal production has risen in recent years. CIL's production grew by 32 MMmt to about 494 MMmt in FY2014–15, whereas in the past it had taken 4 years (FY2011–14) to achieve an increase of 31 MMmt.[130] Some of the recent production growth is attributable to improved mechanization in CIL's Western Coalfields subsidiary and mine expansions in the eastern part of Odisha.[131] Also, as of 2012, CIL began outsourcing production operations at its coal mines to private and foreign companies under a Mine Developers and Operators (MDO) program as one means to improve mechanization and operating expertise. Additional upcoming reforms include CIL's development of a turnkey MDO agreement to promote uniformity, efficiency, and transparency in its outsourcing effort.

### *Private sector coal development in transition*

Anticipating difficulty in keeping pace with projected coal demand, India's government began allowing private mining in 1993, but only for captive purposes (own use). Between 1993 and 2014, a program was in place to encourage the allocation of coal blocks, or licenses to mine. More than 200 blocks were allocated to public and private licensees over that period, but buying and selling the coal produced from the allocated blocks was prohibited, and without the ability to adapt to market conditions, production from the captive blocks changed very little over the decade. For the FY2013–14 period (as of March 2014), 40 captive coal blocks (excluding lignite) were in production, with total production of 39 MMmt out of about 32,000 MMmt of reserves for all active licenses held at the time (138 coal blocks). A total of 61 out of 138 captive coal blocks were licensed to the private sector. They represented one-third of the total captive coal block reserves licensed and accounted for 4% (25 MMmt) of the country's total coal production.[132]

Although the cancellation of coal block allocations was disruptive for the coal supply chain, the government has quickly followed through with new e-auctions of many of the canceled blocks. In March 2015, the Indian Parliament passed the Coal Mines Special Provision Bill, legally allowing commercial coal mining (permitting the resale of coal) by both private and foreign companies with Indian subsidiaries. This bill represents a significant departure for India's coal mining industry, which has been nationalized for more than 40 years, and India has been wary of allowing foreign investment in its fuel minerals industry. In addition, the government is studying the possibility of an e-auction for commercial miners in FY2016. Even with the reforms, however, foreign

*(continued on page 71)*

[130] The Hindu Business Line, "Coal India to invest $20 billion in five years: Goyal" (May 15, 2015), http://www.thehindubusinessline.com/news/coal-india-to-invest-20-billion-in-five-years-goyal/article7209867.ece?utm_source=RSS_Feed&utm_medium=RSS&utm_campaign=RSS_Syndication.

[131] K.N. Das and J. Dash, "Coal India units see double-digit output growth in 2014/15," *Reuters Business News* (February 18, 2014), http://in.reuters.com/article/2014/02/18/coalindia-output-westerncoalfields-idINDEEA1H07F20140218.

[132] Government of India, *Provisional Coal Statistics 2013-14,* p. 32, Table 2.10, "Block wise production of raw coal during 2013-14," and p. 12, "Captive Coal Blocks," http://www.coal.nic.in/sites/upload_files/coal/files/coalupload/provisional1314_0.pdf.

companies still may be reluctant to invest directly in India's coal mines, given the complex permitting process that precedes the start of mine operations.

### *Permitting issues and environmental complications*

Acquisition of a coal block represents the initial step in a long process (including approvals, permits, and land acquisition) toward actual production. Forest clearance permits are required, and typically they have been the most time-consuming part of the process—taking 3 to 6 years (although they can overlap in time with other steps). When successful, the whole process can take up to 8 years, despite the Ministry of Coal's guidelines suggesting a 36- to 42-month span for surface mining operations.[133]

In the past there have been significant environmental challenges for the coal mining industry. For example, just as national production began to grow at a faster rate—7%/year from 2006 to 2009—the Ministry of Environment and Forestry announced a *go, no-go* policy whereby coal block allocations could be rejected outright, depending on the forest density at a particular location. When the Ministry's designation process was completed in 2011, approximately 660 MMmt of coal reserves were labeled as ineligible for mining activity *(no-go)*, affecting 40 CIL projects.[134] Although the original purpose of the policy was to streamline the forestry permitting process, forest clearance permits still lagged for those mines categorized as *go.* From 2009 to 2012, while the policy was in effect, India's total coal production grew by only 2.2%/year. The policy was officially canceled in 2011, but without an immediate replacement, uncertainty continues to affect the permitting process and mine investment. As of August 2015, a new "inviolate forest" policy is pending. Details are not yet available, but early drafts suggest it may be more lenient toward coal mining. Despite its stringency, the *go, no-go* policy did provide clarity, and its absence now leaves coal block licensees in limbo.

Other environmental regulations also have affected coal production. For example, because of a prohibition on mining in industrial geographic clusters that violated the pollution index, CIL production was reduced by 19 MMmt in FY2010–11 and by 39 MMmt in FY2011–12.[135] In addition, a Ministry of Environment and Forestry circular issued in March 2011 stipulated that even if only a portion of a coal block lay under forest, none of it could be mined until all forest clearances were received for the entire block—a practice that had not been followed previously. As a direct effect of this policy, an estimated 11.5 MMmt of CIL coal could not be mined in FY2011–12.[136]

Even with the reallocation of coal blocks in 2015, permitting challenges may continue to obstruct development. A more efficient handling of the permit and approval process will be required to ensure the desired effect of smoother operation of the coal supply chain in the future. To facilitate achievement of India's ambitious production goals, the Ministry of Coal has established a detailed mine plan for CIL development and has established a coal portal database to track the progress of mining projects. The tracking system allows mine licensees to report progress and impediments in gaining their environmental clearances. When delays are noted, the government may intervene in order to speed the processing of applications.

### *Rail infrastructure issues*

Inadequate rail infrastructure and a lack of dedicated freight infrastructure have impeded the growth of India's coal supply. With the bulk of coal reserves concentrated in the northeastern area of the country in the states of Jharkhand, Chhattisgarh, and Odisha, and with coal-fired generating plants located in nearly all the Indian states (Figure 4-14), rail plays a critical role in coal supply. In 2014, as a result of the shortage of transportation capacity, a total of 50 MMmt of coal lay in piles at CIL mines[137] while stockpiles at some generation plants dwindled to 4 days of burn. Decades-long projects—including dedicated freight lines—have yet to be completed, and several rail projects have stalled, including the 93-km Tori-Shivpur-Kathautia line to provide access to coal mines in Jharkhand, which was begun in 1999 and scheduled to be completed in 2005 but was only half complete as of 2015.[138]

In an effort to unlock an additional 300 MMmt of coal,[139] India's government is trying to fast-track three key rail projects that it says will add 100 MMmt of production capacity initially. Among them is the Tori-Shivpur stretch of the Jharkhand rail line, a subset of a full rail project that could open up about 40–50 MMmt of capacity. The second rail project, in Chhattisgarh, will connect Bhupdeopur,

*(continued on page 72)*

[133]Infrastructure Development Finance Company, Ltd., "Captive coal mining by private power developers – Issues and road ahead" (2008), http://www.idfc.com/pdf/publications/captive_coal_mining_final.pdf.

[134]S.P. Singh, "No-go ghost still haunts Coal India" (May 22, 2012), *Business Standard*, http://www.business-standard.com/article/companies/no-go-ghost-still-haunts-coal-india-112052200055_1.html.

[135]*The Economic Times,* "Coal India to take 11.5MT hit on latest green directive; stock up" (June 3, 2011), http://articles.economictimes.indiatimes.com/2011-06-03/news/29617105_1_environment-ministry-coal-projects-forest-clearances.

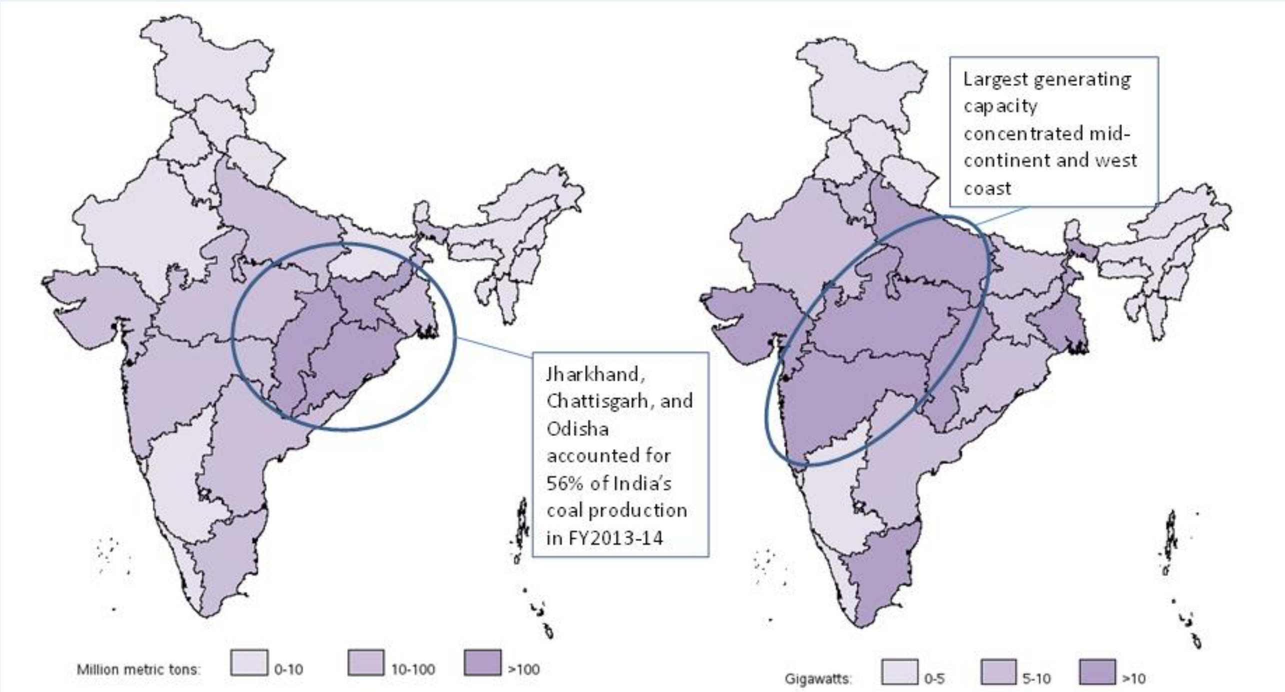
[136]*The Economic Times,* "Government panel says 'Go, No-Go' concept of forest area classification legally not tenable and should be abandoned" (July 29, 2011), http://articles.economictimes.indiatimes.com/2011-07-29/news/29829405_1_environment-ministry-coal-blocks-forest-clearance.

[137]S. Saraf, "India coal: transport bottlenecks as demand is expected to rise" (Platts: May 27, 2015), http://www.platts.com/news-feature/2015/coal/india-coal-transport/index?wt.mc_id=coap201505we_indiarail&wt.tsrc=eloqua.

[138]New Delhi Television, "Government to expedite construction of three rail lines to move coal" (July 8, 2014), http://profit.ndtv.com/budget/government-to-expedite-construction-of-three-rail-lines-to-move-coal-585385; and A. Swarup, "Odisha rail project for coal likely to complete by 2017: Coal India Ltd," *The Times of India: The Economic Times* (April 13, 2015), http://articles.economictimes.indiatimes.com/2015-04-13/news/61103072_1_bhupdeopur-raigarh-mand-area-coal-india-ltd-tori-shivpur-kathautia-area.

[139]Zeenews, "Govt to give priority to 3 critical rail links to carry coal" (May 26, 2014), http://zeenews.india.com/business/news/economy/govt-to-give-priority-to-3-critical-rail-links-to-carry-coal_100279.html.

**Figure 4-14. India's coal production and coal-fired electricity generation capacity by state, FY2013–14**




Raigarh, and Mand Area. The third project, a Jharsuguda-Barpali railway link in Odisha, is slated for the earliest completion, in 2017. CIL's production growth goals depend on the successful and timely completion of these projects. Additional projects also have been proposed, to accommodate an incremental 200 MMmt of coal production capacity.[140] The Dedicated Eastern Freight Corridor—supported by the World Bank—will be an important project for India to move coal northward. With the CIL production path indicating a planned increase of 247 MMmt between FY 2018–19 and FY2019–20,[141] along with its plans to purchase 2,000 rail cars,[142] the government has noted the importance of transportation infrastructure in meeting its goals for coal production.

### *Land acquisition challenges*

Because coal reserves and rail projects, as well as prospective coal-fired generating plants, are in areas under or near privately owned or state-owned land, land acquisition has been a significant barrier to improving the coal supply chain. India is still an agricultural-based economy, with roughly 47% of its workforce engaged in farming,[143] and a new or expanding mine project means displacing not only homes but also livelihoods. As indicated in CIL's updated Rehabilitation and Resettlement Policy, the population affected by land acquisition is an important barrier to robust coal production. The controversial Land Acquisition Reform Act pending in India's parliament may make it easier for the government to force sales of land by private owners, and if it is passed, projects may advance at a faster pace.

A more reliable, growing coal supply would allow more efficient operation of existing coal-fired power plants. For example, an improvement of 5 percentage points in plant utilization alone—without adding any additional coal-fired capacity or displacing any coal imports—would require about 50 MMmt of additional domestic coal production per year.[144]

## World coal trade

### *Imports*

For the three major coal-importing regions represented in IEO2016, overall demand for coal imports in the Reference case is nearly the same in 2040 as in 2013, with total coal imports to Asia slightly higher in 2040, imports to Europe/Other[145] slightly lower, and imports to the Americas in 2040 about the same as in 2013 (Figure 4-15 and Table 4-2).

[140] New Delhi Television, "Government to expedite construction of three rail lines to move coal" (July 8, 2014), http://profit.ndtv.com/budget/government-to-expedite-construction-of-three-rail-lines-to-move-coal-585385.

[141] CNBCTV18 moneycontrol, "Targeting 10% total sales via e-auction route: Coal India" (April 08, 2015), http://www.moneycontrol.com/news/business/targeting-10total-sales-via-e-auction-routecoal-india_1351734.html?utm_source=ref_article.

[142] S. Jha, "Coal India goes for makeover," *The Financial Express* (June 3, 2015), http://www.financialexpress.com/article/industry/companies/coal-india-goes-for-makeover/79443/.

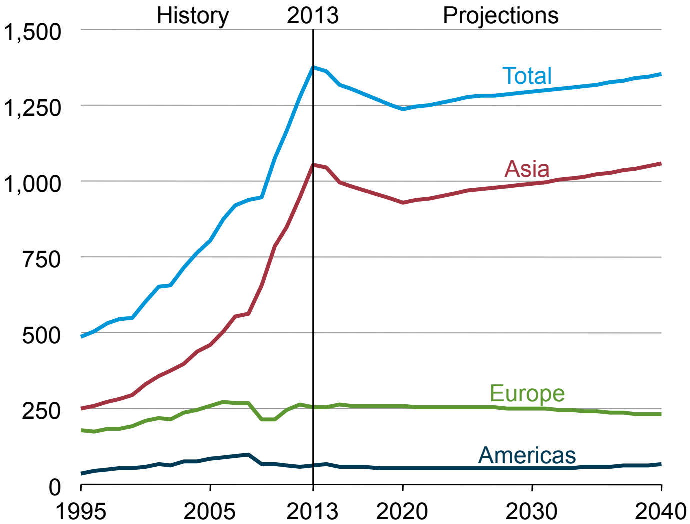
[143] World Bank, "India: Data," http://data.worldbank.org/country/india (2015).

[144] Derived by assuming 200 gigawatts of coal-fired power plant capacity (utility and non-utility plants) and 0.6 MMmt of coal per additional kilowatthour of generation.

[145] Europe/Other includes coal-importing countries in Europe, Eurasia, the Middle East, and Africa.

Asia is the predominant destination for coal exports, with the region's share of total world international coal imports ranging from a low of 75% in 2020 to a high of 78% in 2040. The projected trend for Asian coal imports mirrors that of global demand for coal imports, declining from 1,053 MMst in 2013 to 927 MMst in 2020 and increasing to 1,057 MMst in 2040. The initial decline in Asia's coal imports through 2020 is the result of declining imports to China and India, by 183 MMst from 2013 to 2020. From 2020 to 2040, coal imports to Asia increase by 130 MMst. Coal imports to China and India combined stabilize, with imports to India (primarily coking coal) increasing by 58 MMst and imports to China declining by 50 MMst. Much of the overall growth in coal imports to Asia between 2020 and 2040 is projected for Vietnam, South Korea, Taiwan, and Malaysia. Vietnam's electricity demand is expected to increase substantially in future years, and the government's energy plan indicates that much of the increase will be met by generation from new coal-fired power plants *(see box in Electricity Chapter)*. In the IEO2016 Reference case, coal-fired generating capacity in the countries of non-OECD Asia (including Vietnam, Taiwan, and Malaysia but excluding China and India) increases by 33 gigawatts from 2020 to 2040. In South Korea, coking coal accounts for nearly all of the 25 MMst of incremental growth in coal imports from 2020 to 2040.

**Figure 4-15. World coal imports by major importing region, 1995–2040 (million short tons)**




In the Europe/Other region, total coal imports increase slightly, from 255 MMst in 2013 to 263 MMst in 2015, then decline to 230 MMst in 2040. Coal becomes a less significant component of the region's fuel mix for electricity generation,

**Table 4-2. World coal flows by importing and exporting regions and coal type, Reference case, 2013, 2020, and 2040 (million short tons)**

| | Steam coal | | | Coking coal | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Exporting region | 2013 | 2020 | 2040 | 2013 | 2020 | 2040 | 2013 | 2020 | 2040 |
| | | | | Exports to Europe/Other[a, b] | | | | | |
| Australia | 0.6 | 2.0 | 1.5 | 20.1 | 16.9 | 20.3 | 20.7 | 18.9 | 21.8 |
| United States | 33.5 | 8.4 | 4.9 | 31.2 | 24.9 | 17.0 | 64.7 | 33.2 | 21.8 |
| Southern Africa[c] | 26.9 | 45.3 | 33.8 | 0.3 | 0.0 | 10.0 | 27.2 | 45.3 | 43.8 |
| Eurasia[d] | 57.2 | 59.9 | 56.3 | 5.0 | 4.8 | 6.1 | 62.2 | 64.7 | 62.4 |
| Poland | 7.9 | 3.9 | 3.8 | 0.4 | 1.0 | 0.5 | 8.2 | 4.9 | 4.3 |
| Canada | 0.3 | 0.0 | 2.4 | 4.3 | 10.0 | 4.2 | 4.5 | 10.5 | 6.6 |
| China | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| South America | 58.8 | 78.9 | 68.0 | 0.0 | 0.0 | 0.0 | 58.8 | 78.9 | 68.0 |
| Vietnam and North Korea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Indonesia[e] | 9.2 | 0.5 | 0.7 | 0.0 | 0.4 | 0.4 | 9.2 | 0.9 | 1.1 |
| Total | **194.2** | **198.9** | **171.6** | **61.3** | **58.0** | **58.4** | **255.5** | **256.9** | **229.9** |
| | | | | Coal Exports to Asia[b] | | | | | |
| Australia | 204.8 | 219.7 | 238.6 | 161.2 | 189.4 | 219.4 | 365.9 | 409.2 | 458.0 |
| United States | 8.8 | 8.8 | 15.3 | 18.4 | 8.1 | 0.4 | 27.2 | 16.9 | 15.6 |
| Southern Africa[c] | 51.9 | 43.0 | 48.2 | 3.8 | 9.9 | 17.6 | 55.7 | 52.9 | 65.8 |
| Eurasia[d] | 49.8 | 60.6 | 61.3 | 13.4 | 13.2 | 20.9 | 63.3 | 73.9 | 82.3 |
| Poland | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Canada | 3.2 | 4.4 | 3.6 | 31.2 | 15.4 | 20.0 | 34.4 | 19.8 | 23.6 |
| China | 6.8 | 10.8 | 15.6 | 1.2 | 1.0 | 1.0 | 8.0 | 11.8 | 16.6 |
| South America | 1.1 | 0.0 | 12.8 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 12.8 |
| Vietnam and North Korea | 34.9 | 14.1 | 7.2 | 0.0 | 0.2 | 0.2 | 34.9 | 14.3 | 7.4 |
| Indonesia[e] | 434.4 | 302.6 | 349.2 | 27.6 | 25.9 | 25.9 | 462.0 | 328.5 | 375.1 |
| Total | **795.7** | **664.2** | **751.6** | **256.8** | **263.1** | **305.5** | **1,052.5** | **927.3** | **1,057.1** |

See notes at end of table.

*(continued on page 74)*

with most European countries placing greater emphasis on renewable energy and natural gas for electricity generation. The relatively modest change in imports through 2040 belies some significant shifts within the region. Growth in coal imports for some countries, such as Turkey and Morocco, partially offsets declines for other countries in the region, including the United Kingdom, Germany, Spain, and France.

Environmental initiatives in Europe include efforts to reduce emissions of sulfur dioxide, nitrogen oxide, and particulates, leading to some significant retirements of coal-fired generating capacity and the phasing out of domestic hard coal production in Germany by 2018.[146] Restrictions on carbon dioxide emissions, primarily based on the European Union's Emissions Trading System (ETS), are another potential issue for Europe's coal consumption and imports. Thus far, however, carbon dioxide emission prices have been relatively low and have not significantly affected Europe's coal demand. In contrast, the United Kingdom's recent doubling of its

**Table 4-2. World coal flows by importing and exporting regions and coal type, Reference case, 2013, 2020, and 2040 (million short tons)** ***(continued)***

| | Steam coal | | | Coking coal | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| Exporting region | 2013 | 2020 | 2040 | 2013 | 2020 | 2040 | 2013 | 2020 | 2040 |
| | | | | Coal Exports to America | | | | | |
| Australia | 1.4 | 0.0 | 0.0 | 4.6 | 0.0 | 0.0 | 6.1 | 0.0 | 0.0 |
| United States | 9.7 | 9.3 | 4.7 | 16.0 | 11.9 | 16.3 | 25.7 | 21.2 | 21.0 |
| Southern Africa[c] | 1.5 | 0.1 | 0.1 | 0.3 | 0.0 | 0.0 | 1.9 | 0.1 | 0.1 |
| Eurasia[d] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Poland | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Canada | 0.3 | 0.0 | 0.0 | 3.4 | 8.0 | 12.9 | 3.7 | 8.0 | 12.9 |
| China | 0.0 | 0.2 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.0 |
| South America | 23.2 | 21.8 | 29.3 | 0.0 | 0.0 | 0.0 | 23.2 | 21.8 | 29.3 |
| Vietnam and North Korea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Indonesia[e] | 1.3 | 1.1 | 2.1 | 0.6 | 0.0 | 0.0 | 1.9 | 1.1 | 2.1 |
| **Total** | **37.4** | **32.5** | **37.3** | **24.9** | **19.9** | **29.2** | **62.3** | **52.4** | **66.5** |
| | | | | Total Coal Exports[f] | | | | | |
| Australia | 207.4 | 221.8 | 240.1 | 187.0 | 206.3 | 239.7 | 394.3 | 428.1 | 479.8 |
| United States | 52.0 | 26.5 | 24.8 | 65.7 | 44.8 | 33.7 | 117.7 | 71.4 | 58.5 |
| Southern Africa[c] | 82.5 | 88.4 | 82.2 | 4.5 | 9.9 | 27.6 | 87.0 | 98.3 | 109.7 |
| Eurasia[d] | 107.0 | 120.5 | 117.7 | 18.4 | 18.1 | 27.0 | 125.4 | 138.5 | 144.7 |
| Poland | 7.9 | 4.0 | 4.0 | 0.4 | 1.0 | 0.5 | 8.3 | 5.0 | 4.5 |
| Canada | 3.8 | 4.4 | 6.0 | 38.9 | 33.4 | 37.1 | 42.7 | 37.8 | 43.0 |
| China | 6.8 | 11.0 | 16.5 | 1.2 | 1.0 | 1.0 | 8.0 | 12.0 | 17.5 |
| South America | 83.4 | 100.7 | 110.1 | 0.0 | 0.0 | 0.0 | 83.4 | 100.7 | 110.1 |
| Vietnam and North Korea | 34.9 | 14.1 | 7.2 | 0.0 | 0.2 | 0.2 | 34.9 | 14.3 | 7.4 |
| Indonesia[e] | 445.5 | 304.2 | 352.0 | 28.2 | 26.3 | 26.3 | 473.7 | 330.5 | 378.3 |
| **Total[g]** | **1,031.4** | **895.6** | **960.5** | **344.2** | **341.0** | **393.1** | **1,375.5** | **1,236.6** | **1,353.5** |

[a]Import Regions: **Europe/Other:** Algeria, Austria, Belgium, Bulgaria, Croatia, Denmark, Egypt, Finland, France, Germany, Greece, Ireland, Israel, Italy, Luxembourg, Malta, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Tunisia, Turkey, and the United Kingdom. **Asia:** Bangladesh, China, Hong Kong, India, Iran, Japan, Malaysia, North Korea, Pakistan, Philippines, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam. **America:** Argentina, Brazil, Canada, Chile, Mexico, Puerto Rico, and United States.

[b]Excludes non-seaborne shipments of coal to Europe and Asia. Includes exports to the Middle East and Northern Africa.

[c]Southern Africa consists of the countries of South Africa, Mozambique, and Botswana.

[d]Eurasia consists of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

[e]In 2013, exports from Indonesia include an additional 6.3 million short tons of exports from other countries not included in the forecast period.

[f]Excludes non-seaborne shipments of coal to Europe and Asia.

[g]In 2013, total world coal flows include a balancing item term used to reconcile discrepancies between reported exports and imports. For 2013, the balancing item amounted to 5.2 million short tons.

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

[146]P. Baruya, Impacts of seaborne trade on coal importing countries – global summary, IEA Clean Coal Center, CCC/197 (London, United Kingdom, May 2012), pp. 27-29, http://www.iea-coal.org.uk (subscription site); EURACOAL members and secretariat, EURACOAL Market Report 1/2015, Euracoal (Brussels, Belgium, April 2015), pp. 5-7; and "Turkey Coal Profile," IHS Energy Global Steam Coal Service Country Profiles (September 2015), http://connect.ihs.com/DisplayDocument/Show?source=gi&docid=2437095&connectPath=EmailAlerts&utm_campaign=Immediate%202437095%20from%20gi&utm_source=EmailAlerts&utm_medium=email (subscription site).

Carbon Price Support (CPS) tax (to $28 per metric ton CO2 equivalent in early 2015, which is in addition to the European Union's standard ETS costs) did lead to substantial declines in both coal-fired electricity generation and coal imports for the year.[147]

The countries of OECD Europe accounted for more than 90% of total seaborne coal imports to the Europe/Other region in 2013, and they account for only slightly less than 90% in 2040. Although there is significant overland coal trade among several countries in the non-OECD Europe and Eurasia region, only seaborne shipments of coal for Europe and Asia are represented in EIA's projections, primarily because of data availability problems and the increased complexity associated with modeling non-seaborne coal trade.

Coal imports to the Americas decline from 62 MMst in 2013 to a low of 52 MMst in 2020 in the Reference case, followed by an increase to 67 MMst in 2040. Steam coal imports decline from 37 MMst in 2013 to 32 MMst in 2020, then rise to 37 MMst in 2040, while coking coal imports increase from 25 MMst in 2013 to 29 MMst in 2040. Brazil, which has substantial iron ore resources and was the world's ninth-largest producer of pig iron in 2013,[148] accounts for nearly all the growth in coking coal imports to the Americas region. Relative to global coal trade, the coal import market for the Americas is relatively small, accounting for only about 5% of the world total in both 2013 and 2040.

### *Exports*

Based on the relatively flat outlook for world coal imports, both worldwide and in each of the three major coal-importing regions, exports from some regions increase while exports from other regions decline. The lack of growth in total world coal imports represents a substantial change to the long-term historical trend of continuous annual growth, which led to substantial increases in coal exports for a number of regions. In the IEO2016 Reference case, regions whose coal exports increase from 2013 to 2040 include Australia (85 MMst), Southern Africa (23 MMst); Eurasia (19 MMst), and South America (27 MMst). On the other side of the ledger, declines in exports from 2013 to 2040 are projected for Indonesia (-95 MMst), the United States (-59 MMst), and Vietnam/North Korea (-28 MMst).

Most of the world's coal trade consists of steam coal. In 2013, the top five exporters of steam coal were Indonesia, Australia, Eurasia (primarily Russia), South America (primarily Colombia), and Southern Africa (primarily South Africa) *(see box below).* Indonesia, which was the world's largest exporter of steam coal in 2013, remains the top exporter through 2040. The three top exporters of coking coal in 2013 were Australia, the United States, and Canada; and despite a substantial drop in coking coal exports from the United States and increases in exports from Southern Africa and Eurasia, the same countries continue to be the top three exporters of coking coal through 2040.

A substantial portion of the growth in coal exports projected for Australia and Southern Africa from 2013 to 2040 is attributable to increases in coking coal imports to Asia. Australia's exports of steam coal also grow somewhat, primarily as the result of recent improvements in coal mining productivity that have improved the cost competitiveness of their exports relative to those from other regions.[149] The projected increase in coking coal exports from Southern Africa is attributable primarily to investments in new mining capacity and transportation infrastructure that are underway in Mozambique with the goal of exploiting its substantial deposits of coking-quality coals.[150, 151]

## Recent developments in world coal trade

From 2008 to 2013, international seaborne shipments of coal increased by 47%, from 937 MMst to 1,376 MMst (Figure 4-16). Most of the growth in world coal trade occurred in Asia. The Americas and the Europe/Other region (Europe, Eurasia, Middle East, and Africa)[152] saw modest declines in overall coal imports—by 34 MMst and 14 MMst, respectively.[153] From 2009 to 2013, world

*(continued on page 76)*

[147]B. Lee, "UK fuel switch gains traction but road not smooth," ICIS (November 16, 2015), http://www.icis.com/resources/news/2015/11/16/9944374/analysis-uk-fuel-switch-gains-traction-but-road-not-smooth; and J. Holman, "UK July thermal coal imports fall 71% on-year to 821,375 mt," *Platts Coal Trader International*, Vol. 15, No. 175 (October 14, 2015), pp. 1 & 11, http://www.platts.com (subscription site).

[148]World Steel Association, *Steel Statistical Yearbook 2015* (Brussels, Belgium: 2015), pp. 91-92, https://www.worldsteel.org/statistics/statistics-archive/yearbook-archive.html.

[149]Australian Government, Department of Industry and Science, Office of the Chief Economist, *Coal in India* (June 2015), pp. 79-83, http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Coal-in-India.aspx.

[150]Financial pressures related to the recent decline in both international coal trade and prices have led some companies to back away from their investments in Mozambique's coal industry (e.g., Rio Tinto sold its three coal mining projects in the country to the Indian company International Coal Ventures Private Limited (ICVL) in 2014 for a price much lower than it paid for them in 2011). However, other companies have remained and are continuing to move forward with their investment projects. For example, Vale is continuing its work to complete a 567-mile rail line to the port of Nacala in Mozambique. That project, scheduled for completion in 2016, will have an initial annual coal transport capacity of 20 MMst. Upgrades to the 357-mile Sena Railway, also underway, will increase its annual transport capacity from 7 MMst to approximately 22 MMst by June 2016.

[151]K. Campbell, "Mozambique's coal sector still embattled, but bottlenecks should soon go," *Creamer Media's Mining Weekly* (October 16, 2015), http://www.miningweekly.com/article/mozambiques-coal-sector-still-embattled-but-bottlenecks-should-soon-go-2015-10-16; P. Fauvet, "Tata Steel to Sell Benga Coal Assets," *allAfrica* (February 20, 2015), http://allafrica.com/stories/201505131549.html; J. Rowland, "Vale coal production down y/y in 3Q15," *World Coal* (October 21, 2015), http://www.worldcoal.com/mining/21102015/Vale-coal-production-down-year-on-year-in-3Q15-3041; and L. Caruana, "Isaac Plains, Integra reduce Vale's coal output," *International Coal News* (October 21, 2015), http://www.internationalcoalnews.com/storyview.asp?storyID=826957202&section=News&sectionsource=s46&aspdsc=yes.

[152]Europe/Other includes the countries of Europe, Eurasia, the Middle East, and Africa.

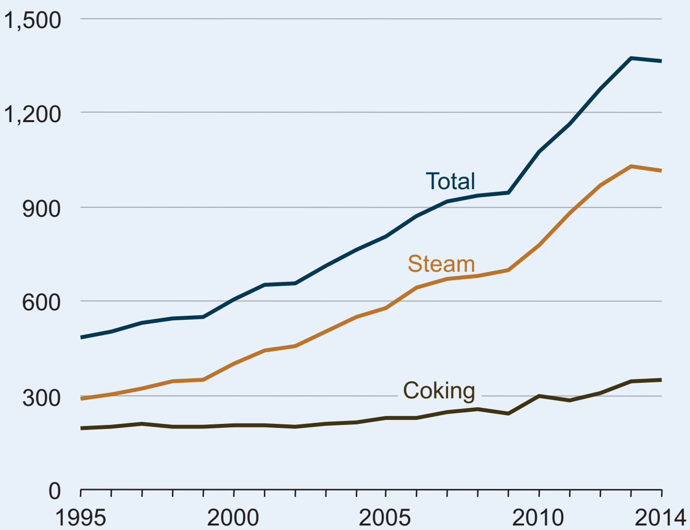
[153]U.S. Energy Information Administration, "International energy data and analysis," http://www.eia.gov/beta/international/.

coal trade grew by approximately 100 MMst each year, surpassing the previous high of 69 MMst from 2005 to 2006. However, the data for 2014 and 2015 indicate a retreat from the record-breaking 2009–13 increases in annual trade, with declines in China's coal imports currently on pace to more than offset increases in other countries during both years (Figure 4-17).

### *Coal imports*

Almost all (98%) of the 2008–13 growth in world coal trade involved imports to Asia by China and India (Figure 4-18). China's imports rose from 45 MMst in 2008 to 341 MMst in 2013, and India's imports rose from 69 MMst in 2008 to 203 MMst in 2013. Steam coal imports accounted for 74% and 90% of the growth in coal imports to China and India, respectively, with coking coal accounting for the remainder. The increases in coal imports by China and India resulted primarily from mismatches between domestic coal supply and demand, as coal production and transportation infrastructure were unable to keep up with increases in domestic coal use.

**Figure 4-16. World coal trade by coal type, 1995–2014 (million short tons)**




India's coal imports continued to rise in 2014 and through the first half of 2015, as demand rose at a faster pace than domestic coal supplies. In China, however, coal imports fell in 2014 and are estimated to have declined further in 2015.[154] Increased output from China's domestic coal mines, improvements in its coal transportation infrastructure, and minimal growth in domestic coal demand improved the balance between domestic supply and demand in 2014 and 2015, resulting in lower prices for domestic coal supplies and reducing demand for coal imports. In addition, the Chinese government introduced a number of measures in late 2014 and early 2015 to support the domestic coal industry, including taxes on coal imports (3% for anthracite and coking coal and 6% for thermal coal); limits on allowable sulfur, ash, and trace elements in imported coal; and a directive for major utilities to reduce their annual coal imports by a combined total of approximately 55 MMst.[155]

The markets for world coal trade present significant challenges in terms of their predictability. On the demand side, the recent emergence of China and India—both of which have substantial

*(continued on page 77)*

**Figure 4-17. Annual changes in total world coal trade, 1995–2014 (million short tons)**

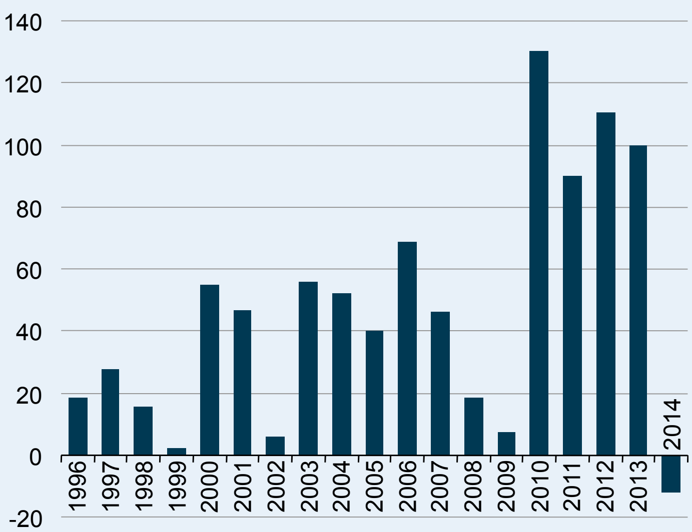
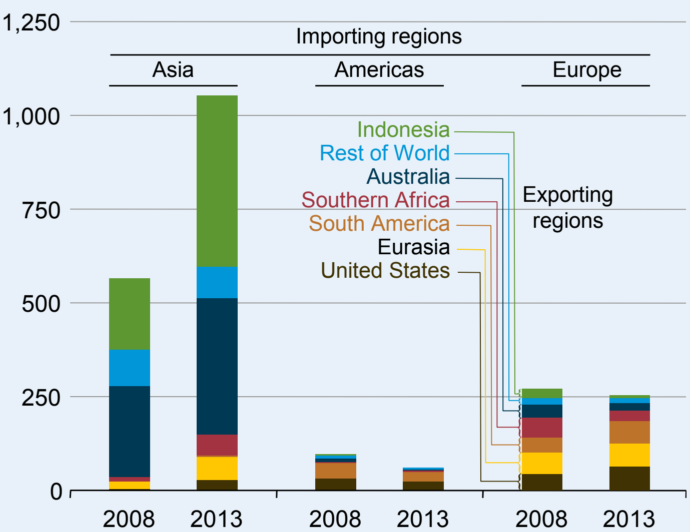



**Figure 4-18. World coal trade by importing and exporting regions, 2008 and 2013 (million short tons)**




[154] Xiaomin Liu and Shan Xue, "China Coal Market Briefing: Third quarter 2015" *IHS Energy* (August 2015), p. 2, http://connect.ihs.com/DisplayDocument/Show?source=gi&docid=2831005&connectPath=EmailAlerts&utm_campaign=Immediate%202831005%20from%20gi&utm_source=EmailAlerts&utm_medium=email (subscription site).

[155] R. Somwanshi, "After import tariff, China to impose coal resource tax," *SNL Energy Extra* (October 13, 2014), http://www.snl.com (subscription site); J. Yang, "China reinstates coal import tariffs to support domestic miners," *Bloomberg News* (October 9, 2014), http://www.bloomberg.com/news/articles/2014-10-09/china-reinstates-coal-import-tariffs-to-support-domestic-miners; and Australian Government, Department of Industry and Science, Office of the Chief Economist, *Resources and Energy Quarterly,* Vol. 4, No. 3 (Canberra, Australia: March 2015), pp. 49-50, http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Resources-and-energy-quarterly.aspx.

coal resources and well-developed coal industries—as major coal-importing countries increases the complexity of the Pacific market. In the past, most of the coal trade in Pacific markets was based on a more predictable buildup of coal-fired generating capacity and integrated steelmaking capacity in countries such as Japan, South Korea, and Taiwan, which have very little domestic coal production and are almost entirely dependent on imports. More recently, however, China's domestic seaborne shipments of coal (primarily consisting of coal shipped from loading ports in northeastern China to unloading ports located along the eastern and southern coasts) have expanded rapidly, creating the possibility of substantial variations in its coal imports, depending on the domestic and imported coal prices. Recent data indicate that China's annual domestic seaborne shipments and imports of coal together amounted to about 1 billion short tons, or about one-fourth of its total annual coal consumption.[156] India, which imported approximately 25% of the coal it consumed in 2013, has ambitious goals to more than double domestic coal production between 2013 and 2020, which conceivably could eliminate its need for imports of steam coal.[157] However, India's history of failing to meet production targets and not completing major coal transportation projects leads to considerable uncertainty regarding its future requirements for coal imports.[158]

### Coal exports

Coal exports from producers in Indonesia and Australia satisfied most of the increase in demand for imports over the 2008–13 period, with Indonesia's exports growing by 247 MMst (56% of the total increase) and Australia's exports growing by 106 MMst (24% of the total increase) over that period (Figure 4-18). Among the other suppliers, exports from Eurasia and the United States increased by 49 MMst and 36 MMst, respectively, over the same period. In contrast, China's coal exports fell substantially, from 50 MMst in 2008 to 8 MMst in 2013.

By coal type, Australia's exports of both steam coal and coking coal increased from 2008 to 2013, while nearly all of the increase in Indonesia's exports consisted of steam coal. In 2006 Indonesia surpassed Australia as the world's largest supplier of steam coal, and in 2013 it accounted for more than 40% of the world's seaborne shipments of steam coal. Australia has continued to dominate world trade in coking coal, accounting for more than 50% of all international shipments in 2013.

World coal export supplies and patterns are constantly changing and evolving and, similar to coal imports, can be challenging to predict. As noted, the recent surge in demand for coal imports has led to substantial increases in coal exports from Australia and Indonesia, both of which benefit from their close geographic proximity to China and India. At the same time, the large expansion in the Pacific coal market has led to a shift in Southern Africa's coal exports from Europe to Asia, substantial growth in Eurasia's export shipments to the Pacific market, and a revival in U.S. coal exports to Asia. In turn, Southern Africa's substantial shift away from the Atlantic to the Pacific coal market, combined with reduced exports from Australia and Indonesia to Europe, has led to increased exports to Europe from both the United States and South America.

In addition to changes in international demand for coal imports, coal export supplies are susceptible to a host of often unpredictable factors, such as floods, labor strikes, changes in government policies, and transportation bottlenecks. Examples of some recent supply disruptions include heavy rains and flooding from a strong La Niña weather phenomenon that slowed coal exports from Colombia in 2010, heavy rains and flooding in late 2010 and early 2011 that reduced coking coal exports from Australia in 2011, and labor strikes and rebel attacks on rail lines that adversely affected coal exports from Colombia in 2013.

The increase in world coal trade from 2008 to 2013 resulted in some sharp increases in international coal prices (both steam and coking coal), as coal exporters struggled to bring on additional coal mining and transportation capacity (Figure 4-19 and Figure 4-20). In turn, the elevated prices provided an opportunity for higher-cost suppliers to participate in international markets. For example, U.S. coal producers, which typically act as swing suppliers in world coal markets, had effectively been locked out of coal markets in Asia for several years until 2008–12, when much higher international prices for steam coal and coking coal allowed U.S. coal exports to generate positive financial returns. In 2014 and 2015, however, world coal trade showed relatively little growth, and expansions of coal production capacity, primarily in Australia, led to substantial reductions in coal export prices and decreases in coal exports from higher cost supplies, including exports from U.S. coal mines.

### Uncertainties in future prospects for international coal trade

Currently, international coal trade is on track for a modest decline in 2015. Looking forward, however, there are considerable uncertainties about future levels and distribution patterns for world coal trade. They include the question of how demand for coal imports in China and India will evolve in coming years. Although both countries are working to expand domestic coal production and complete major new coal transportation infrastructure projects, it is possible that either country could become more dependent on coal imports in the future. In addition, other countries in Asia also have the potential to increase coal imports substantially, given that coal-fired power plants generally are cost-competitive in the region, particularly in comparison with natural gas-fired power plants

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[156] Argus Consulting Services, *Argus Seaborne Thermal Coal Report,* Issue 15-11 (November 6, 2015), p. 5, http://www.argusmedia.com (subscription site); and personal communication (e-mail) from Mr. Hayden Atkins, Argus Consulting Services, New York, NY (November 23, 2015).

[157] R. Somwanshi, "Government eyes zero Indian coal imports by 2020, experts say not possible," *SNL Daily Coal Report,* Vol. 9, No. 43 (March 6, 2015), pp. 10-11, http://www.snl.com (subscription site).

[158] U.S. Energy Information Administration, "India's coal industry in flux as government sets ambitious coal production targets," *Today in Energy* (Washington, DC: August 25, 2015), http://www.eia.gov/todayinenergy/detail.cfm?id=22652.

that to a large extent rely on imports of liquefied natural gas. In Vietnam, where electricity demand has been increasing at a rapid pace in recent years, there are ambitious plans to increase coal-fired generating capacity. As of January 2016, more than 12 GW of coal-fired capacity was under construction, and there are plans to add an additional 60 gigawatts of new coal-fired generating capacity by 2030, much of which is expected to be fueled by imported coal.[159] Evolving environmental policies also have the potential to affect world coal consumption and, consequently, coal trade. In particular, significant commitments to reduce greenhouse gas emissions worldwide could lead to substantial reductions in coal use by key coal-importing countries in both Asia and Europe.

Uncertainties about coal export supplies also loom large. Indonesia's government has been assessing the potential need to curtail its coal exports to assure adequate supplies of domestic coal for planned additions to its coal-fired generating capacity, including announced plans to add 20 gigawatts of new coal-fired capacity by the end of 2020.[160] Australia, which during the boom years of 2008–13 was having difficulty adding sufficient new mining and transportation capacity to meet demand for its coal exports, now has excess coal mining capacity. Other factors affecting the outlook for world coal export supplies and distribution patterns include whether industry will be successful in financing and completing major new coal export projects across the globe, and how coal prices (including both mining and transportation cost components) will change over time. Examples of major new projects oriented toward coal exports include new mining, rail, and port projects currently under development in Mozambique; plans by Adani Enterprises Ltd.to develop the large Carmichael mine in Australia's Galilee Basin; and the proposed Gateway Pacific and Millennium coal export facilities in the U.S. Pacific Northwest.[161]

**Figure 4-19. Average annual steam coal export prices by country of origin, 1990–2014 (2013 dollars per short ton, f.o.b. port of exit)**

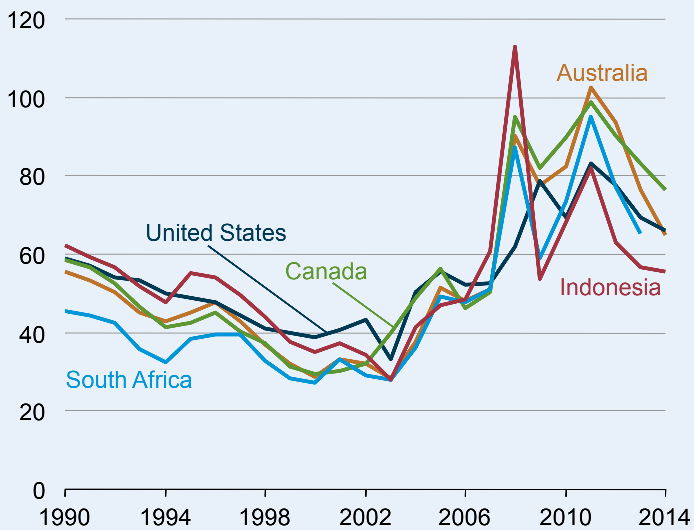
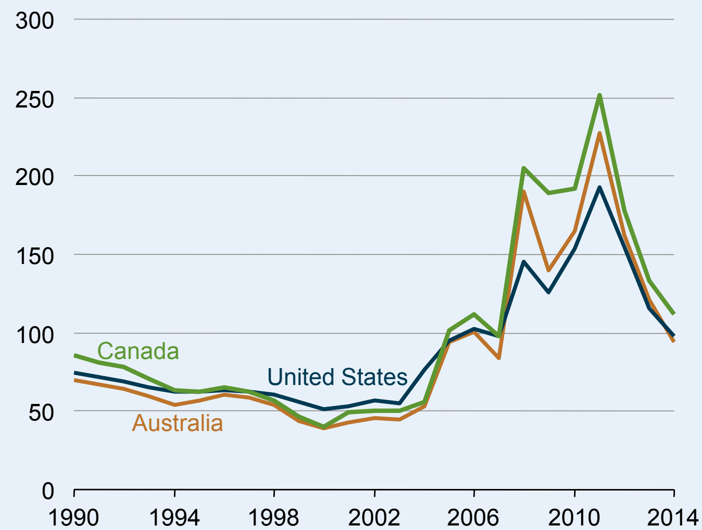



**Figure 4-20. Average annual coking coal export prices by country of origin, 1990–2014 (2013 dollars per short ton, f.o.b. port of exit)**




### *World coal reserves*

As of January 1, 2012, total recoverable reserves of coal around the world were estimated at 978 billion tons—providing a reserves-to-production ratio of approximately 110 years (Table 4-3). Historically, estimates of world recoverable coal reserves, although relatively stable, have declined gradually from 1,145 billion tons in 1991 to 909 billion tons in 2008.[162, 163] In the most recently published reserves data (as of January 1, 2009, and January 1, 2012), estimates of total world coal reserves increased, with new

[159] R. Somwanshi, "Coal 'importing is inevitable' for Vietnam, expert says," *SNL Energy* (November 19, 2014), http://www.snl.com (subscription site); E. Adourian, "Global Steam Coal Service: Vietnam Coal Profile" *IHS Energy* (July 2015), http://connect.ihs.com (subscription site); and C. Shearer et al., *Boom and Bust 2016: Tracking the Global Coal Plant Pipeline* (March 2016), p. 38, http://sierraclub.org/sites/www.sierraclub.org/files/uploads-wysiwig/final%20boom%20and%20bust%202017%20(3-27-16).pdf.

[160] R. Somwanshi, "Global coal exports slip in April, but continued growth in seaborne markets seen," *SNL Energy Exclusive* (June 30, 2015), http://www.snl.com (subscription site).

[161] Mitsui & Co., "News release: Mitsui to participate in Coal and Rail & Port Infrastructure Business in Mozambique" (December 9, 2014), https://www.mitsui.com/jp/en/release/2014/1203631_5699.html; R. Somwanshi, "Major banks end advisory roles, cast doubt over big coal project in Australia," *SNL Energy Extra* (August 11, 2015), http://www.snl.com (subscription site); and M. Christian, "West Coast coal terminal developers keep eyes on prize in face of opposition," *SNL Energy Exclusive* (June 12, 2015), http://www.snl.com (subscription site).

[162] Recoverable reserves are those quantities of coal that geological and engineering information indicates with reasonable certainty can be extracted in the future under existing economic and operating conditions. The reserves-to-production ratio is based on reserves estimates and data on world coal production for 2012 (Table C3).

[163] U.S. Energy Information Administration, *International Energy Annual 1991,* DOE/EIA-0219(91) (Washington, DC: December 1992), Table 33, https://books.google.com/books?id=2JEtMwEACAAJ&dq=International+Energy+Annual+1991&hl=en&sa=X&ved=0ahUKEwi51N6UlNLJAhVDQSYKHRHJD9kQ6AEIHTAA; and *Annual Energy Review 2009,* DOE/EIA-0384 (2009) (Washington, DC, August 2010), Table 11.13, http://www.eia.gov/totalenergy/data/annual/index.cfm.

assessments for Germany (2009) adding 37 billion tons of recoverable coal reserves, Indonesia (2012) adding 25 billion tons, and Turkey (2012) adding 7 billion tons. Although the overall decline in estimated reserves from 1991 to 2012 was sizable, the large reserves-to-production ratio for world coal indicates that sufficient coal will be available to meet demand well into the future. Further, because recoverable reserves are a subset of total coal resources, recoverable reserve estimates for a number of regions with large coal resource bases—notably, China and the United States—could increase substantially as coal mining technology improves and additional geological assessments of coal resources are completed.

Although coal deposits are widely distributed, 76% of the world's recoverable reserves are located in five regions: the United States (26%), Russia (18%), China (13%), non-OECD Europe and Eurasia outside of Russia (10%), and Australia/New Zealand (9%). In 2012, those five regions together produced 6.4 billion tons of coal, or 72% of total world coal production by tonnage. By rank, anthracite and bituminous coal account for 45% of the world's estimated recoverable coal reserves on a tonnage basis, subbituminous coal accounts for 32%, and lignite accounts for 23%.

Quality and geological characteristics of coal deposits are important parameters for coal reserves. Coal is heterogeneous, with quality (for example, characteristics such as heat, sulfur, and ash content) varying significantly by region and even within individual coal seams. At the top end of the quality spectrum are premium-grade bituminous coals, or coking coals, used to manufacture coke for the steelmaking process. Coking coals produced in the United States in 2012 had an estimated heat content of 28.7 million Btu/ton and a relatively low sulfur content of approximately 0.9% by weight. At the other end of the spectrum are reserves of low-Btu lignite. On a Btu basis, lignite reserves show considerable variation. Estimates published by the International Energy Agency for 2012 indicate that the average heat content of lignite in major producing countries varies from a low of 4.8 million Btu/ton in Greece to a high of 12.9 million Btu/ton in Canada.

**Table 4-3. World recoverable coal reserves as of January 1, 2012 (billion short tons)**

| | 2012 | 2020 | 2025 | 2030 | | |
|---|---|---|---|---|---|---|
| Region/Country | Bituminous and anthracite | Sub-bituminous | Lignite | Total | 2012 production | Reserves-to-production ratio (years) |
| **World total** | **442.4** | **314.3** | **221.2** | **977.9** | **8.898** | **110** |
| United States[a] | 117.5 | 106.3 | 32.9 | 256.7 | 1.016 | 253 |
| Russia | 54.1 | 107.4 | 11.5 | 173.1 | 0.392 | 442 |
| China | 68.6 | 37.1 | 20.5 | 126.2 | 4.256 | 30 |
| Other non-OECD Europe and Eurasia | 42.2 | 18.5 | 39.9 | 100.9 | 0.358 | 282 |
| Australia and New Zealand | 40.9 | 2.5 | 41.4 | 84.8 | 0.418 | 203 |
| OECD Europe | 5.7 | 0.9 | 61.9 | 66.8 | 0.630 | 106 |
| India | 61.8 | 0.0 | 5.0 | 61.6 | 0.666 | 92 |
| Other non-OECD Asia | 2.2 | 31.6 | 5.6 | 34.9 | 0.663 | 53 |
| Africa | 34.8 | 0.2 | 0.0 | 14.7 | 0.296 | 50 |
| Other Central and South America | 8.0 | 0.6 | 0.0 | 8.6 | 0.103 | 84 |
| Brazil | 0.0 | 7.3 | 0.0 | 7.3 | 0.007 | 995 |
| Canada | 3.8 | 1.0 | 2.5 | 5.0 | 0.073 | 69 |
| Other[b] | 2.6 | 0.8 | 0.1 | 3.6 | 0.021 | 170 |

[a]Data for the U.S. represent recoverable coal estimates as of January 1, 2014.
[b]Includes Mexico, Middle East, Japan, South Korea, and Greenland.

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# 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)**

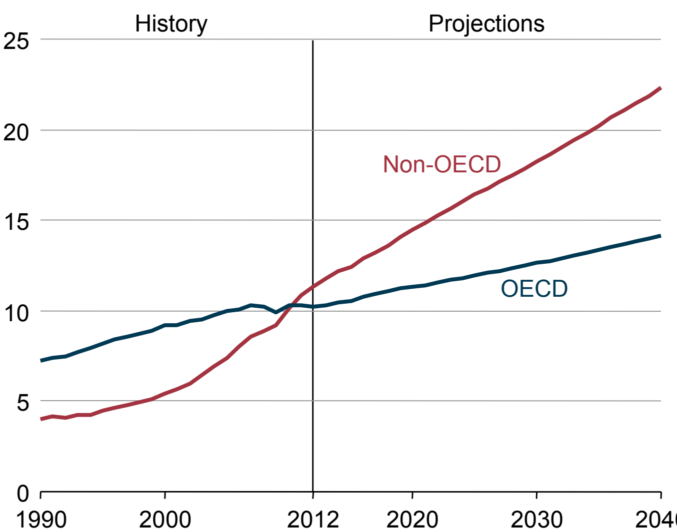
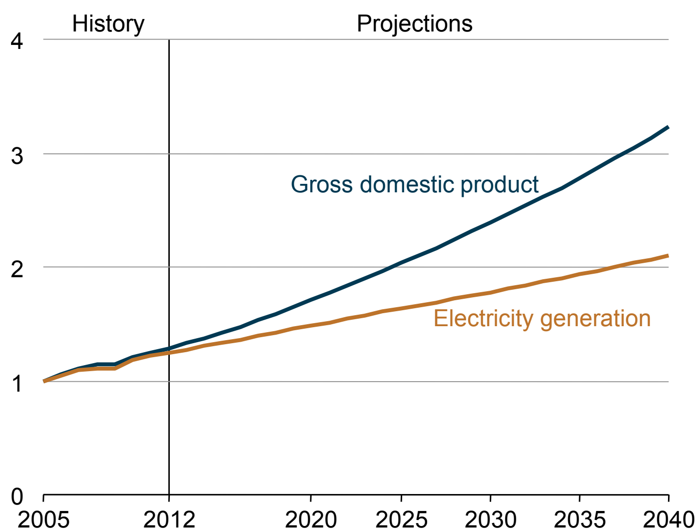



**Figure 5-2. Growth in world electricity generation and GDP, 2005–40 (index, 2005 = 1)**




[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).

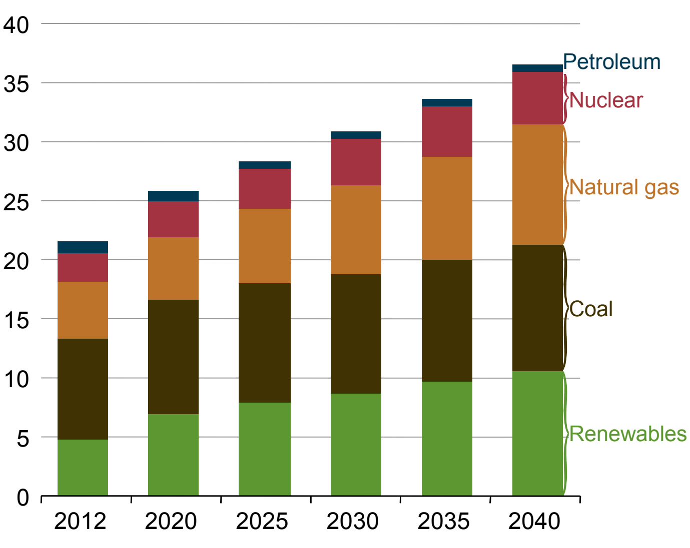
## Electricity generation by source

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.

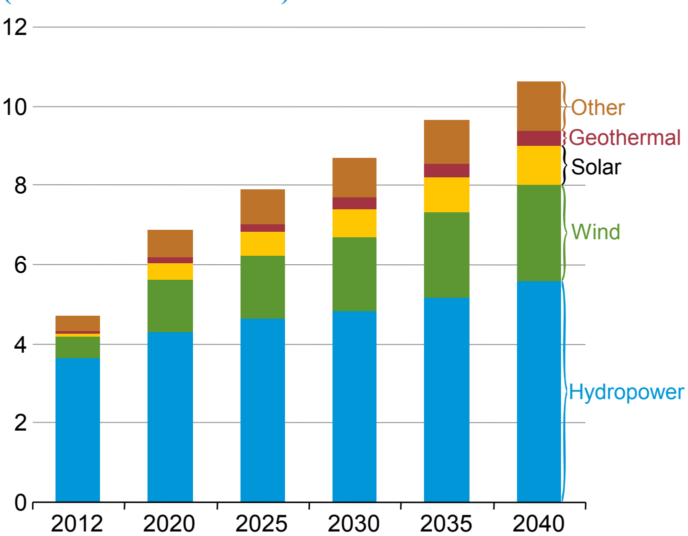
### Renewable resources

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,

*(continued on page 86)*

### 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)**

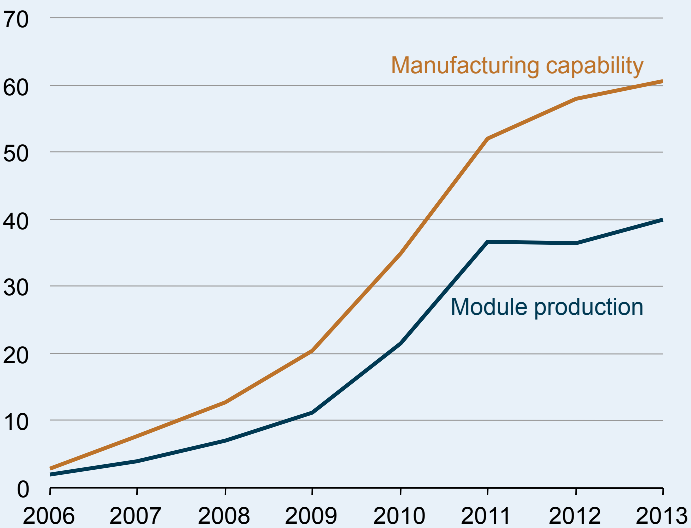
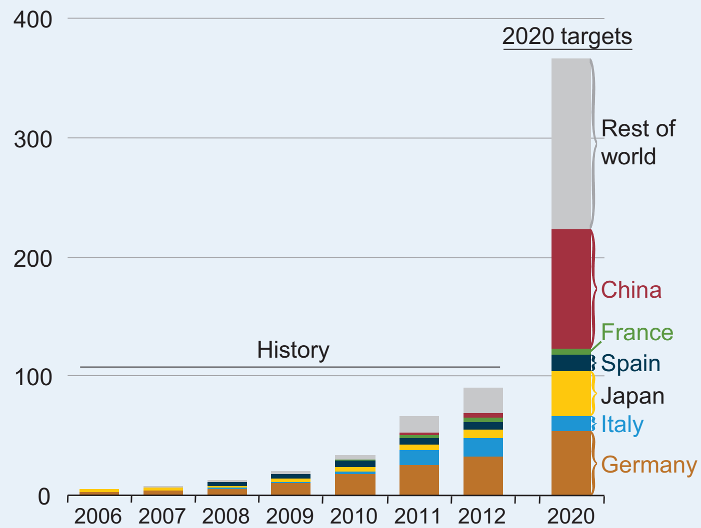



**Figure 5-6. World installed solar photovoltaic capacity by country, 2006–12, and projected total installed capacity in 2020 (gigawatts)**




## 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.

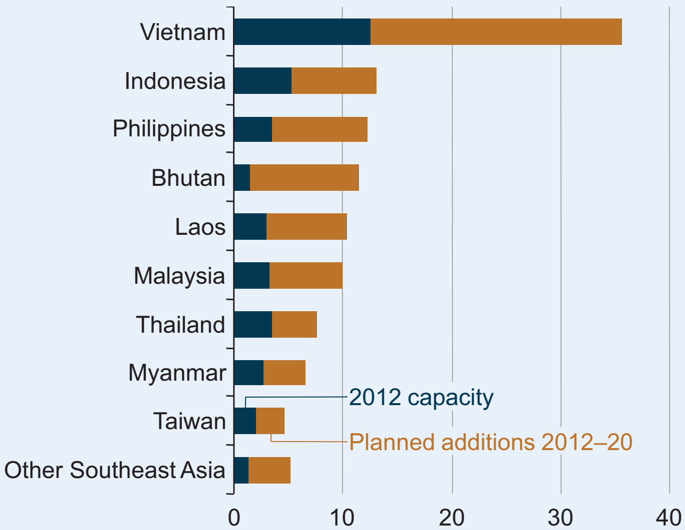
[173]U.S. Energy Information Administration, International Energy Statistics database (Washington, DC: October 2015), http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=7&cid=r7,&syid=2008&eyid=2012&unit=MK.

[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.

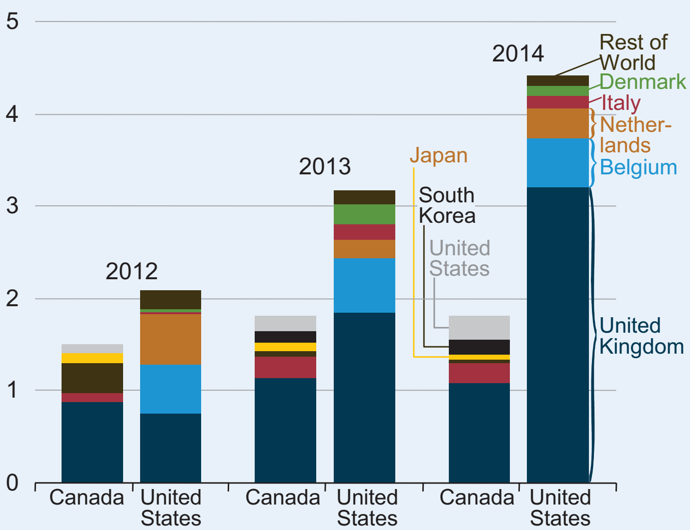
The increase in consumption of wood pellets in Europe is primarily a result of the European Commission's 2020 climate and energy plan, which calls for a reduction in greenhouse gas emissions and an increase in renewable energy as a percentage of total energy consumption,[184] with individual member states 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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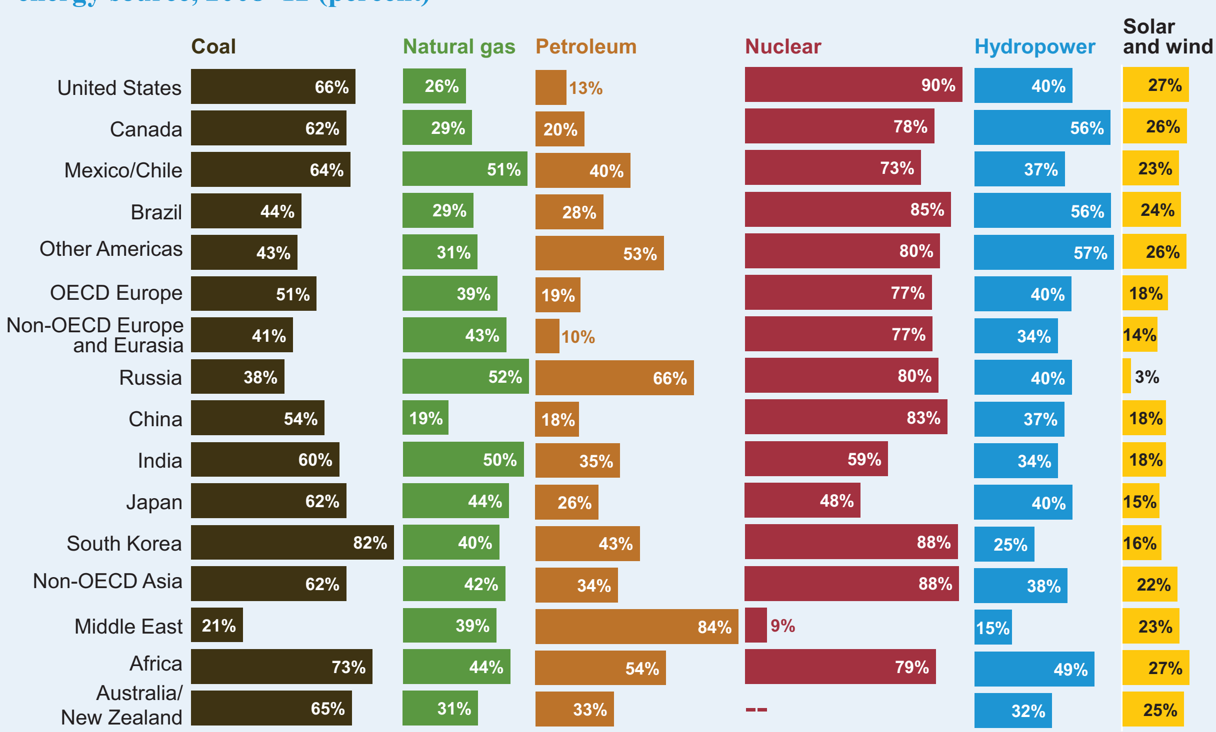
**Figure 5-9. Average annual capacity factors for electricity generators by IEO region and energy source, 2008–12 (percent)**




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

*(continued on page 91)*

[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.

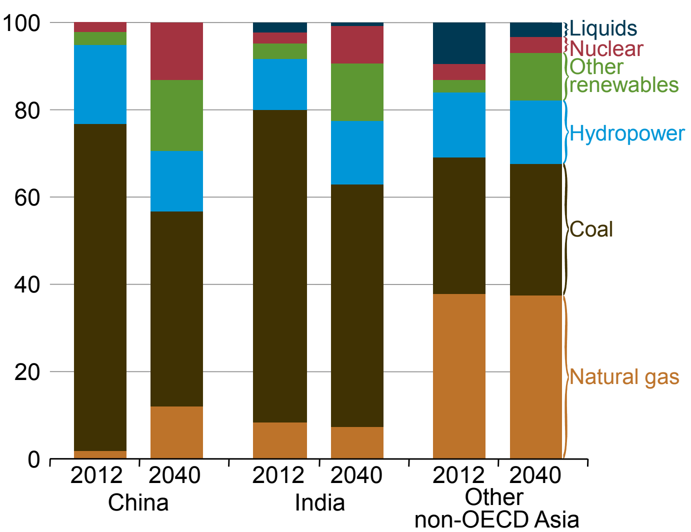
Despite significant public opposition to nuclear power in Japan,[199] two nuclear reactors at Sendai[200] were restarted in 2015 under new safety standards put in place after the 2011 Fukushima disaster. In Europe, Germany aims to move from fossil fuel-based electricity generation to a largely carbon-free 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]

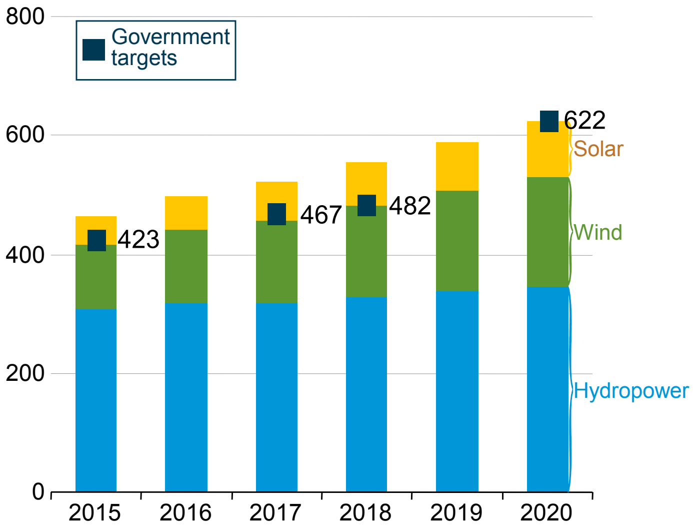
At the time of the announcement of its commitment to peak emissions in 2030, China's government officials estimated that to achieve that target it would be necessary to build 800–1,000 gigawatts of non-emitting generating capacity by 2030, thus offering a comparative benchmark for projections.[205]

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

*(continued on page 94)*

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

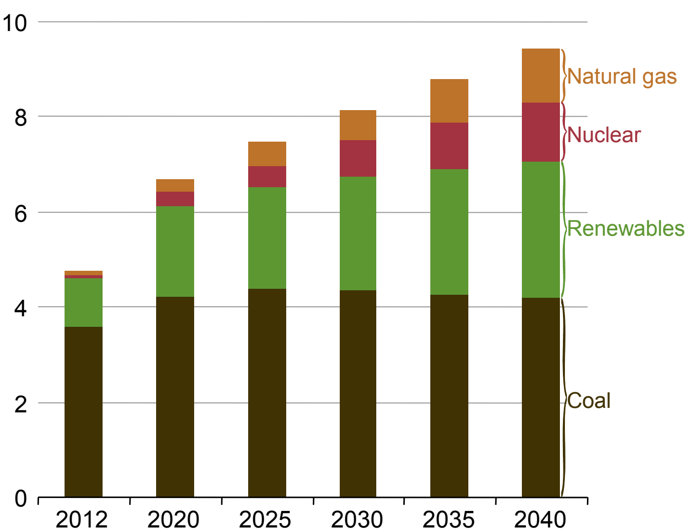
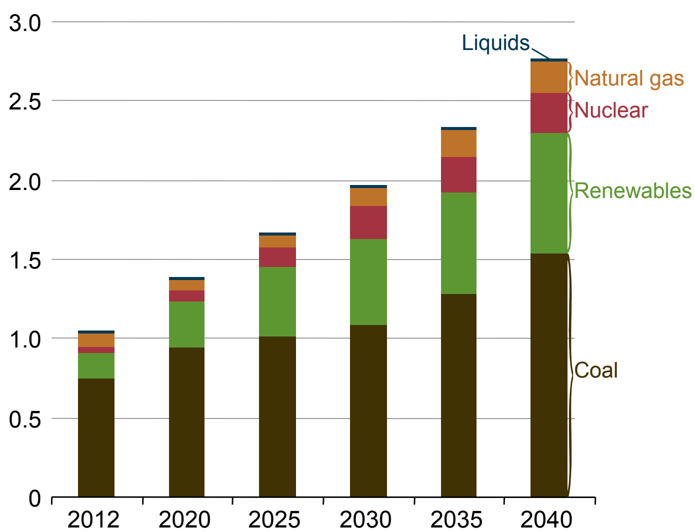



**Figure 5-13. India electricity generation by fuel source, 2012–40 (trillion kilowatthours)**




[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.

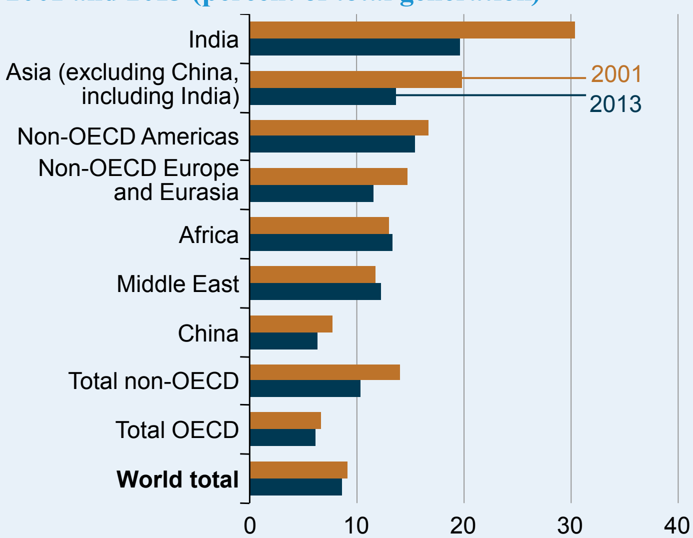
Central Electricity Authority, which is responsible for overall development of the power sector, expects a total electricity shortage of 2.1%, and a peak demand shortage of 2.6%, in FY 2015. Improving T&D losses by even a few percentage points would help lower the country's electricity shortages and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

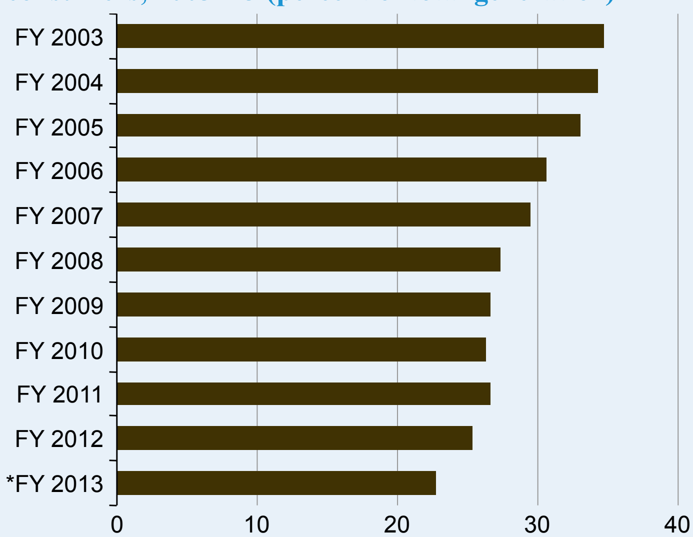
[222] Power Finance Corporation Ltd., *A Report on the Performance of State Power Utilities for the years 2010-11 to 2012-13* (May 2014), http://www.pfcindia.com/writereaddata/userfiles/file/Report%20for%20the%20years%202010-11%20to%202012-13%20Final.pdf.

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]

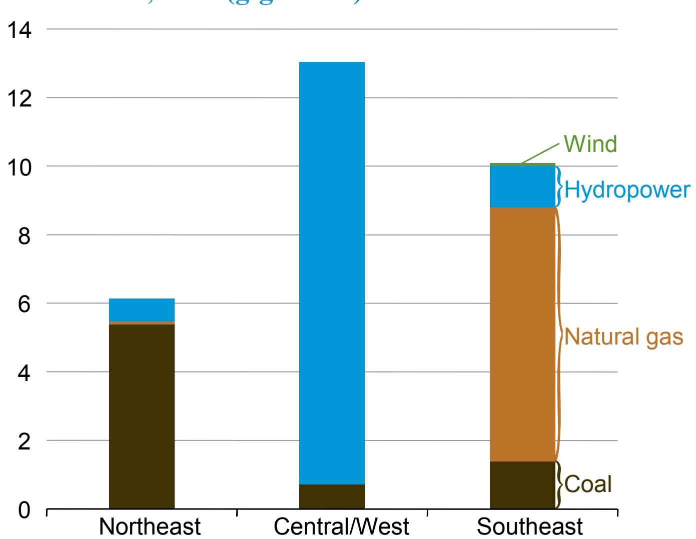
In 2012, 72% of India's electricity was generated at coal-fired power plants; that share falls to 55% in 2040 in the IEO2016 Reference case. According to the International Energy Agency, a shortage of coal and natural gas supplies for power generation is a pressing issue for India's power sector. Domestic 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]

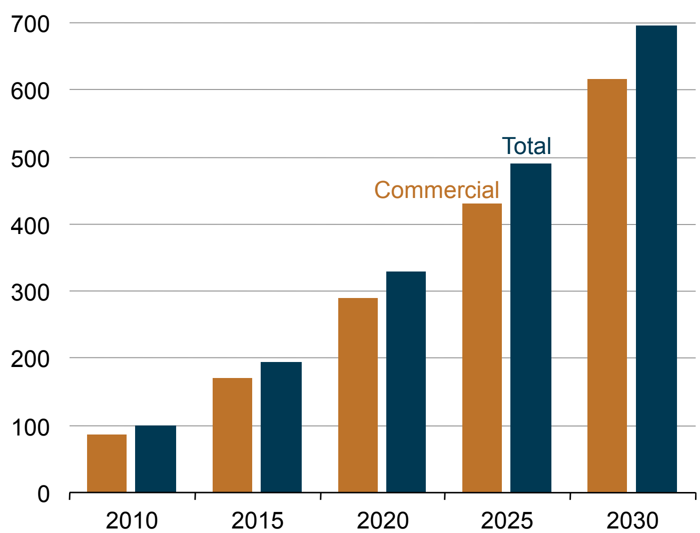
Although Vietnam currently has no nuclear generation capacity, deposits of uranium ore (U3O8 content greater than 0.015%) in the northern and central regions are estimated at 660 million pounds.[242] Vietnam's nuclear fuel-cycle policy calls for survey and exploration of its uranium reserves to determine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

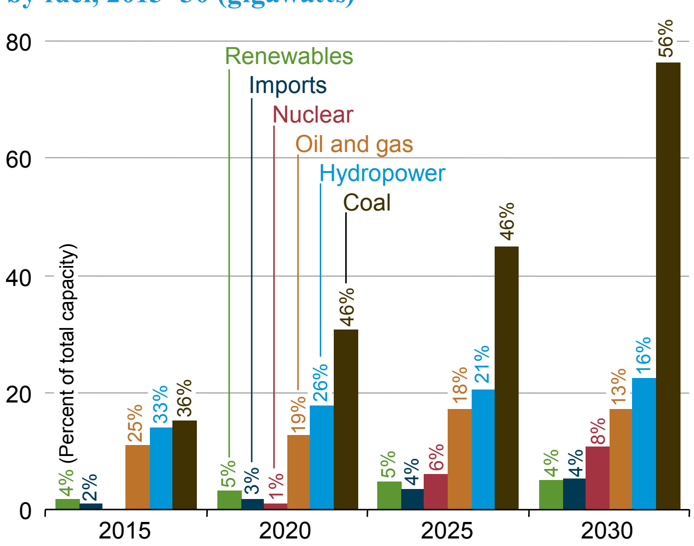
PetroVietnam is seeking to import 11 million tons of coal per year starting in 2017 to supply the domestic power industry, according to a PetroVietnam Power and Coal Import and Supply Company official quoted by Reuters.[245] The coal imports would supply three power plants—two in the southern Mekong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



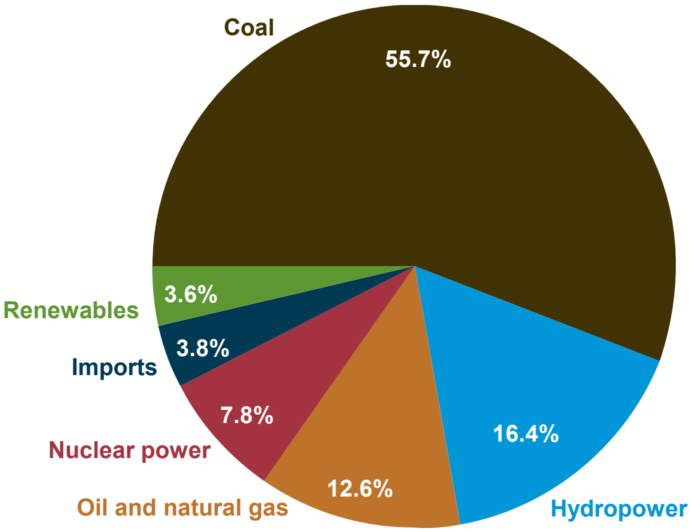

In the IAEA 2013 Vietnam Country Nuclear Power Profile, Vietnam reported that its generation capacity mix will change significantly by 2030, with coal-fired generation projected to dominate the country's total installed capacity. GSO projections indicate that coal-fired capacity will increase from 36% 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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Chapter 6

# Buildings sector energy consumption

## Overview

Energy consumed in the buildings sector consists of residential and commercial end users and accounts for 20.1% of the total delivered energy consumed worldwide. Consumption of delivered, or site, energy contrasts with the use of the primary energy that also includes the energy used to generate and deliver electricity to individual sites such as homes, offices, or industrial plants. In the *International Energy Outlook 2016* (IEO2016) Reference case, delivered energy consumption in buildings worldwide increases by an average of 1.5%/year from 2012 to 2040. In the non-Organization for Economic Cooperation and Development (non-OECD) nations, consumption of delivered energy in buildings grows by 2.1%/year from 2012 to 2040, nearly three times the growth rate for the OECD nations.

## Residential sector

Energy consumption in the residential sector includes all energy consumed by households, excluding transportation uses.[253] It includes energy used for heating, cooling, lighting, water heating, and consumer products. Energy consumption in the residential sector is affected by income levels, energy prices, location, building and household characteristics, weather, efficiency and type of equipment, energy access, availability of energy sources, and energy-related policies, among other factors. As a result, the type and amount of energy consumed by households can vary significantly within and across regions and countries.

In the IEO2016 Reference case, residential sector energy use accounts for about 13% of total world delivered energy consumption in 2040. Delivered energy consumption in the residential sector grows by an average of 1.4%/year from 2012 to 2040, increasing by a total of 48% over the entire period. Residential energy use in the non-OECD nations increases by an average of 2.1%/year from 2012 to 2040 in the Reference case and accounts for 80% of all growth in world residential energy use over the 28-year period. OECD residential sector energy use grows much more slowly, averaging 0.6%/year over the same period, but residential energy consumption per capita remains higher in OECD countries than in non-OECD countries through 2040.

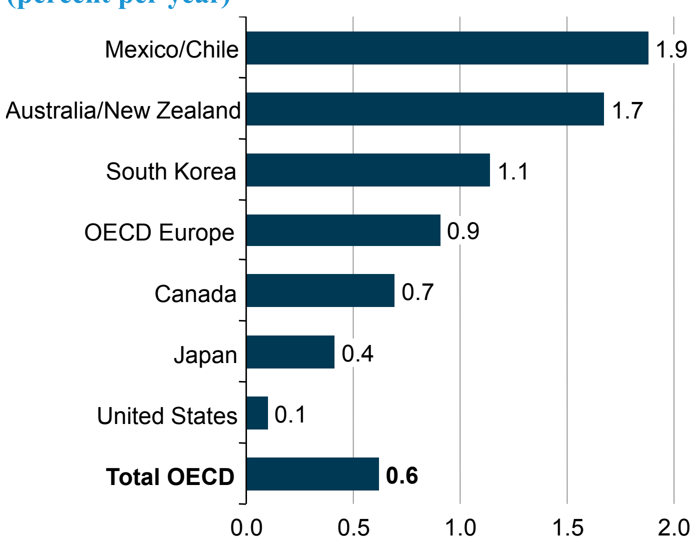
Electricity becomes an increasingly important energy source for the residential sector throughout the projection period. The electricity share of world residential energy consumption grows from 39% in 2012 to 43% in 2040, and by 2025 electricity surpasses natural gas as the leading source of residential delivered energy.

China and India continue to lead world residential energy demand growth in the IEO2016 Reference case, mainly as a result of their relatively fast-paced economic growth. In 2040 their combined residential energy consumption is more than double their 2012 total and accounts for nearly 27% of total world residential energy consumption.

### *OECD residential energy consumption*

For the OECD region, residential energy consumption increases by an average of 0.6%/year from 2012 to 2040 in the IEO2016 Reference case (Figure 6-1). The lower growth rate in comparison with other world regions is a result of relatively slow growth in gross domestic product (GDP) and population, as well as improvements in building shells and the efficiency of appliances and equipment. The OECD share of the world's residential energy consumption declines from 50.2% in 2012 to 40.4% in 2040, as demand rises among the emerging economies of the non-OECD. Over the projection period, OECD residential energy use per capita grows by an average of 0.2%/year (Figure 6-2).

**Figure 6-1. Average annual change in OECD residential sector energy consumption, 2012–40 (percent per year)**




In the IEO2016 Reference case, as demand for household electronics increases, electricity surpasses natural gas as the largest source of energy for OECD residential use, accounting for 43% of total residential consumption in 2040. Accordingly, the shares of fossil fuels, including natural gas, liquid fuels, and coal, decrease. Residential sector electricity demand grows by an average of 1.0%/year over the projection period and natural gas consumption grows by 0.6%/year, compared with a decline of 0.3%/year for coal and liquid fuels.

#### *OECD Americas*

Residential energy consumption in the countries of the OECD Americas (United States, Canada, Chile, and Mexico) accounts for one-fourth of the world's total delivered residential energy consumption in 2012. The United States is by far the largest consumer of residential energy in the OECD Americas, accounting for 84% of the OECD Americas total in

[253] Total delivered energy used in the residential and commercial sectors includes electricity, natural gas, liquid fuels, coal, and marketed renewable energy (*e.g.*, solar thermal energy).

2012 and 80% in 2040. Residential energy consumption in the United States remains steady between 2012 and 2040 as state and federal energy efficiency standards for consumer products, other efficiency programs, and sectoral changes offset drivers that would otherwise increase residential energy demand.

Although they consume far less energy than the United States, the economies of Chile and Mexico grow more rapidly than the other parts of the OECD Americas from 2012 to 2040. The combined residential energy consumption of Mexico and Chile grows by an average of 1.9% annually from 2012 to 2040, compared with 0.1% in the United States. Mexico and Chile together have the highest projected growth rates in GDP (as measured in purchasing power parity terms) in the OECD region, at 3.1%/year from 2012 to 2040, compared with 2.0%/year for the OECD overall. This strong economic growth leads to improvement in standards of living and increased residential demand for space heating and air conditioning and other energy-consuming household products. In 2012, petroleum and other liquid fuels accounted for the largest share of residential energy use in Mexico and Chile (Figure 6-3). In the Reference case, their share declines from 55% in 2012 to 32% in 2040. Electricity becomes the major residential energy source for Mexico and Chile combined, increasing from 37% of their total energy use in 2012 to 60% in 2040.

### *OECD Europe*

Many countries in OECD Europe have instituted measures to improve energy efficiency in the residential sector. Those efforts, along with relatively low economic growth and slow population growth, contribute to the slow increase in the region's residential energy use through 2040. Households in OECD Europe accounted for 21% of the world's total residential energy consumption in 2012, but their share falls to 18% in 2040 in the IEO2016 Reference case, with the region's total residential sector energy demand increasing by an average of only 0.9%/year. Electricity is OECD Europe's fastest-growing source of residential energy in the IEO2016 Reference case, with consumption growth averaging 1.4%/year from 2012 to 2040, while natural gas consumption grows at a rate of 1.0%/year.

### *OECD Asia*

The total residential demand for energy in OECD Asia increases by an average of 0.8%/year in the IEO Reference case. Japan accounts for the largest share of residential energy use in OECD Asia throughout the projection, although its share declines from 63% in 2012 to 56% in 2040. In Japan, residential sector energy consumption grows by 0.4% annually from 2012 to 2040 in the Reference case, with GDP growing by 0.6%/year and population declining by 0.4%/year. The residential sector accounts for more than one-third of total electricity consumption in Japan, mostly from the use of residential electronic appliances. Electricity remains Japan's main residential energy source throughout the projection, increasing by 0.5%/year from 2012 to 2040.

## *Non-OECD residential energy consumption*

Residential energy consumption in the non-OECD countries accounted for less than 50% of the world's total residential energy use in 2012. Their share grows to nearly 60% in 2040 in the IEO2016 Reference case, as a result of generally faster economic and population growth than in the OECD countries. Total residential sector demand for energy in the non-OECD countries increases by an average of 2.1%/year in the Reference case, led by an average annual increase of 3.2% in India from 2012 to 2040 (Figure 6-4). Electricity consumption leads the increase in non-OECD residential energy use. Electricity's share grows from 31% in 2012 to 47% in 2040, as many emerging economies transition from traditional fuels to marketed fuels, and the quality of life improves with access to modern sources of energy, especially electricity.

**Figure 6-2. Average annual change in OECD residential sector energy consumption per capita, 2012–40 (percent per year)**

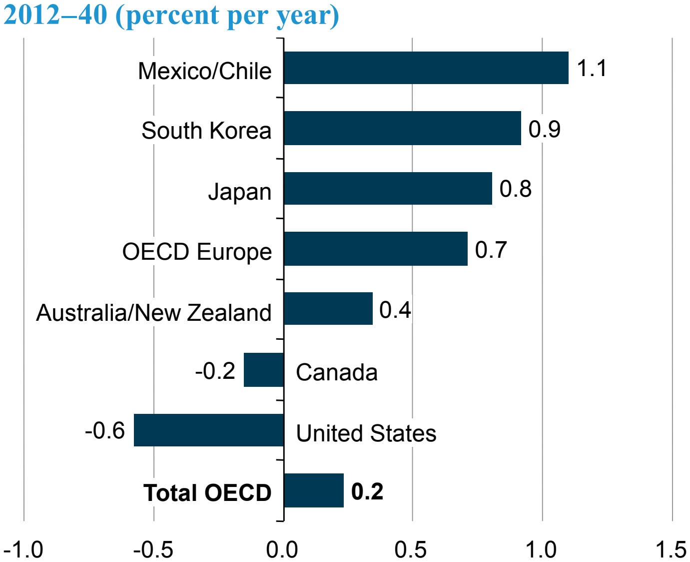
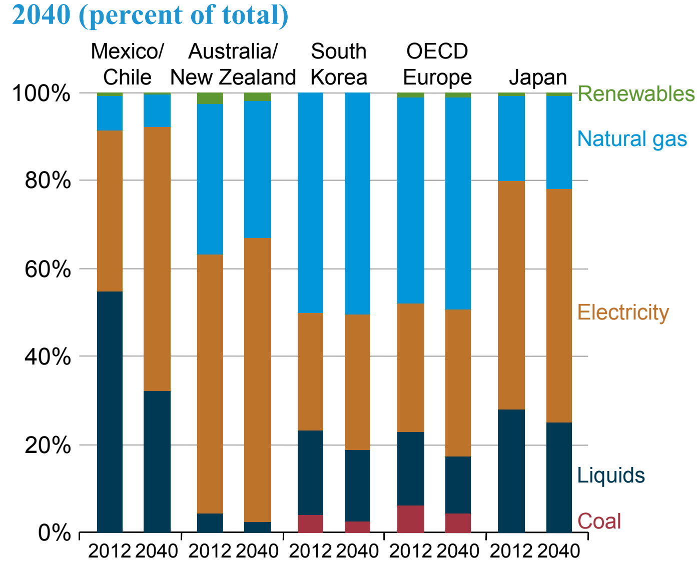



**Figure 6-3. Residential sector energy consumption in selected OECD regions by energy source, 2012 and 2040 (percent of total)**



### *Non-OECD Asia*

China and India account for 27% of the world's residential energy consumption in 2040, in the IEO2016 Reference case, up from 19% in 2012. The importance of China in world residential energy demand continues to increase, accounting for 20% of the world total in 2040. Residential energy use in China grows by an average of 2.4%/year from 2012 to 2040. In 2012, China's residential energy consumption was 80% of the level in the United States; in 2040 it is 50% higher than in the United States, and China becomes the world's largest residential energy consumer.

The rapid growth in China's residential sector energy consumption is mainly the result of strong economic growth and urbanization, as lifestyle and energy use patterns vary widely between urban and rural populations.[254] According to the United Nations, nearly three-fourths of the Chinese population will live in urban areas by 2040.[255] China's demand for energy services increases as per capita income and quality of life improve, accompanied by an increase in urban population and increased access to nontraditional fuels in rural areas. In the Reference case, China's residential energy use per capita grows by 2.3%/year from 2012 to 2040 (Figure 6-5).

## Effects of urbanization on energy demand and greenhouse gas emissions in China

The advent of China's economic reform in the late 1970s has led to "the largest migration in human history,"[256] with more than 160 million people moving from farming communities to cities to seek employment in growing industries. Rapid urbanization also is occurring in other developing countries, leading to concerns that accelerating economic growth in emerging market countries and their adoption of Western patterns of energy consumption will undermine efforts to limit greenhouse gas (GHG) emissions. Of particular interest is whether lessons can be learned from the Chinese experience of urbanization regarding energy consumption in the residential sector.

Research has shown that urban density and spatial dispersion are key determinants of residential energy consumption.[257] Switching from a rural to an urban dwelling typically is associated with a shift from the use of traditional biomass fuels (such as wood and waste) to the use of more modern fuels (such as natural gas for heating), with greater potential for energy efficiency measures. Multicountry studies of the effects of urbanization on energy use[258] have shown two opposing effects: improvements in energy-using equipment, such as air conditioning units, associated with an urban lifestyle increase efficiency, but higher numbers of households and increased penetration of air conditioning increase energy use.

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**Figure 6-4. Average annual change in non-OECD residential sector energy consumption, 2012–40 (percent per year)**

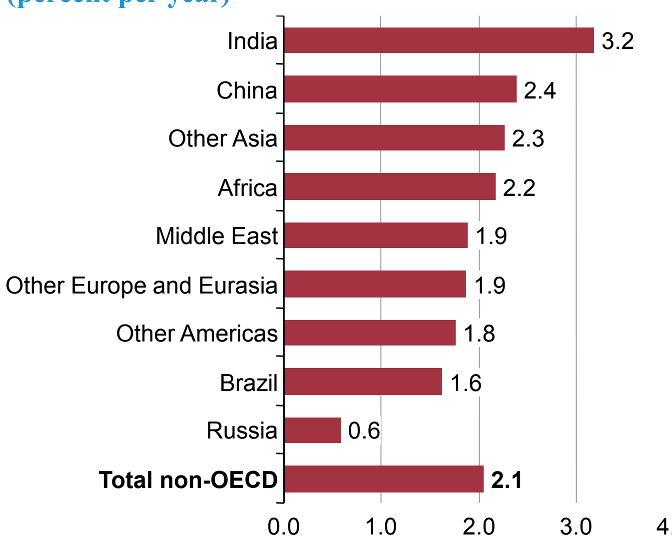
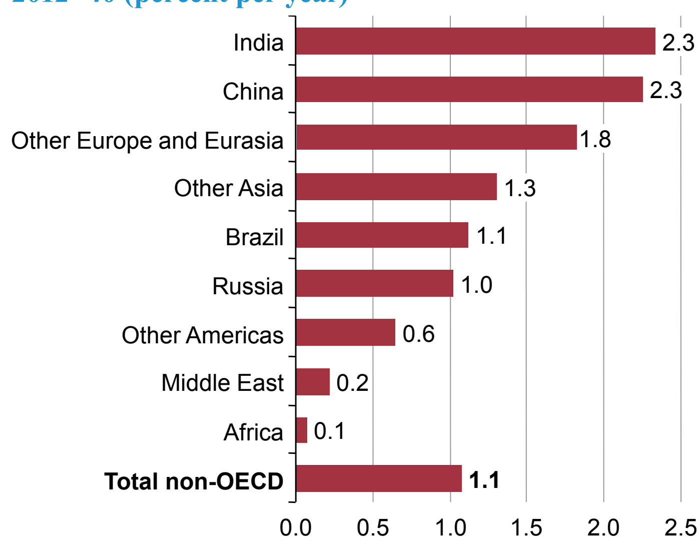



**Figure 6-5. Average annual change in non-OECD residential sector energy consumption per capita, 2012–40 (percent per year)**




[254] R. Vasudevan, K. Cherail, R. Bhatia, and N. Jayaram, *Energy Efficiency in India: History and Overview* (Alliance for an Energy Efficient Economy, New Delhi, India, December 2011), pp. 16-17, http://aeee.in/wp-content/uploads/2014/09/AEEE-EE-Book-Online-Version-.pdf.

[255] United Nations, Department of Economic and Social Affairs, Population Division, "World Urbanization Prospects: The 2014 Revision, CD-ROM Edition" (November 2014), http://esa.un.org/unpd/wup/CD-ROM/.

[256] "The largest migration in history," *The Economist,* Free Exchange Blogs (February 24, 2012), www.economist.com/blogs/freeexchange/2012/02/china (subscription site).

[257] E. Safirova, S. Houde, and W. Harrington, *Spatial Development and Energy Consumption* (Washington, DC: Resources for the Future, December 2007), http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-07-51.pdf.

[258] Wang Qing Song, "Research on air environmental impact of urbanization development strategy in Shandong Province" (Ph.D. Dissertation, Shandong University: 2010), http://www.topresearch.org/showinfo-53-213750-0.html.

China's regulated approach to urbanization (requiring permits for residence in some cities, high-density urban housing developments) appears to have resulted in less energy-intensive development than in other emerging market countries. From 1990 to 2012 the percentage of China's population residing in urban areas doubled—from 26% to 52%—and according to World Bank statistics, residential energy consumption nearly tripled (Figure 6-6), from 4 quadrillion Btu to 11 quadrillion Btu. Energy use per capita in China rose by 1.8%/year from 1990 to 2000 (from 30.5 million Btu to 36.5 million Btu per capita), as compared with 0.8%/year in OECD countries, and by 8.0%/year from 2001 to 2012, when energy use per capita averaged 85.1 million Btu (Figure 6-7). In comparison, energy use per capita in the OECD countries declined by 0.8%/year from 1990 to 2012. However, China's energy use per capita in 1990 was one-fifth of the OECD average, and despite China's more rapid rate of growth, it was still only one-half of the OECD average in 2012.

**Figure 6-6. Residential energy consumption and urban population growth in China, 1990–2012 (index, 1990 = 1.0)**

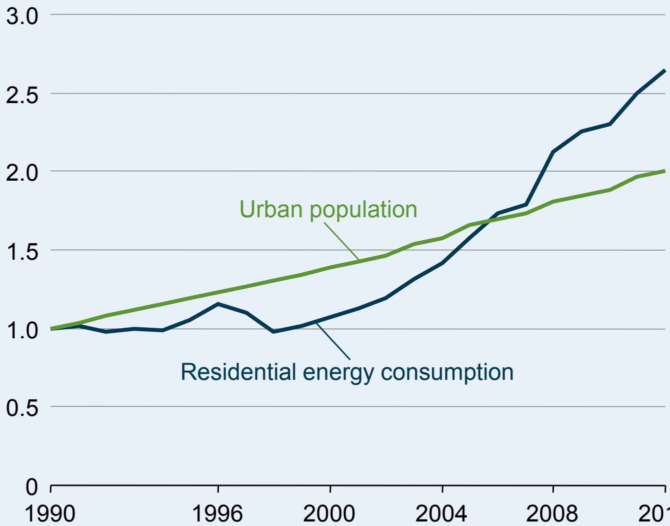
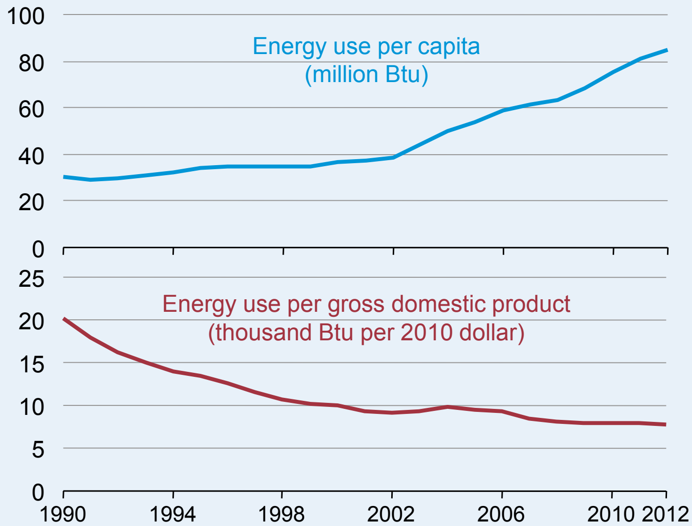
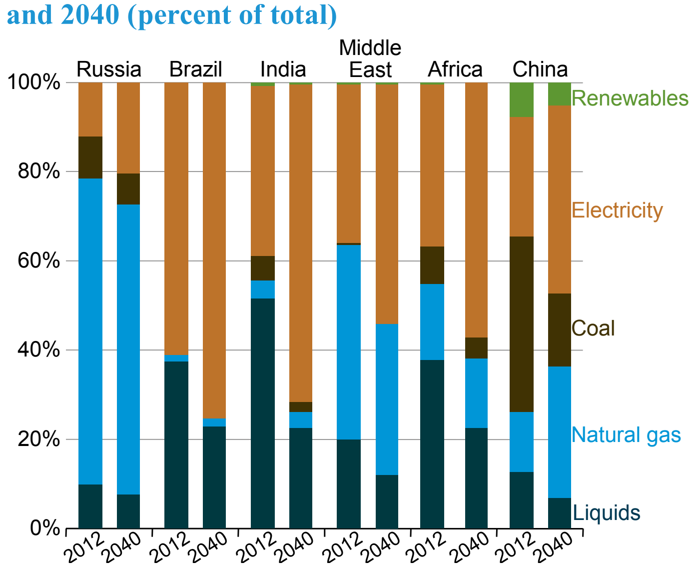



**Figure 6-7. China's residential sector energy consumption per capita and per thousand dollars of GDP, 1990–2012**




China's residential fuel mix shifts towards electricity and natural gas over the projection period (Figure 6-8). In the Reference case, although residential natural gas consumption in China grows faster than electricity use as natural gas prices decline, electricity nevertheless becomes the major source of energy for the residential sector, accounting for 42% of the residential sector total in 2040. China's government has been engaged in promoting energy efficiency in residential buildings since the 1980s, and it continues to promote building energy efficiency in its latest Five-Year Economic Plan. Even with the strong emphasis on improving building energy efficiency *(see text box below),* the country's residential energy consumption grows strongly over the projection due to various factors, including rapid economic growth, improvement in standards of living, and additions of new buildings to house the expanding urbanized population.[259]

**Figure 6-8. Residential sector energy consumption in selected non-OECD regions by energy source, 2012 and 2040 (percent of total)**




In India, residential energy consumption has been affected by the government's various energy efficiency programs for household appliances and buildings, particularly since 2002, with the establishment of the Bureau of Energy Efficiency.[260] However, as in China, residential sector energy consumption in India continues to increase throughout the Reference case projection, as a result of rising standards of living and increasing urbanization. In the IEO2016 Reference case, residential energy consumption in India grows by 3.2%/year, with GDP increasing by 5.6%/year from 2012 to 2040—the highest rate of economic growth among the 16 IEO regions.

[259] S. Bin and L. Jun, "Building Energy Efficiency Policies in China: Status Report," p. 74 (American Council for an Energy-Efficient Economy, Research Report E129, July 2012), http://aceee.org/research-report/e129.

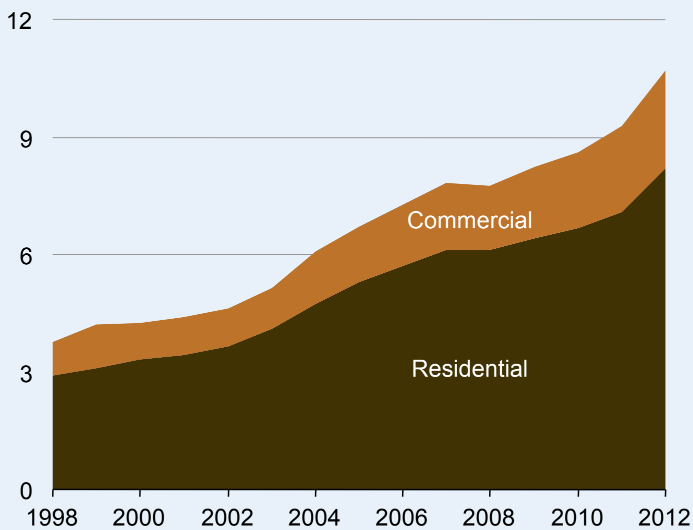
[260] S-J Ahn and D. Graczyk, *Understanding Energy Challenges in India: Policies, Players, and Issues* (International Energy Agency, Paris, France, 2012), https://www.iea.org/publications/freepublications/publication/India_study_FINAL_WEB.pdf.

## China's policies to increase energy efficiency in buildings

From 1998 to 2012, energy consumption in China's buildings increased by about 7.7%/year (Figure 6-9), much faster than China's average annual population increase, which was less than 1%/year. Growing incomes and modernization contributed to the significant increase in consumption of electricity and other forms of energy. In an effort to reduce energy consumption in residential and commercial buildings, China has implemented various energy efficiency policies and programs, including building energy codes, green building ratings, minimum energy performance standards, voluntary ratings programs, and energy-efficiency retrofits in existing buildings.

China issued its first building energy codes in 1986 for residential buildings in the northern part of the country where demand for space heating is highest. The 1986 codes required a 30% reduction in energy use for space heating compared with reference buildings from 1980, and the stringency of subsequent codes has increased over time.[261] There are currently three energy codes for residential buildings in four climate zones (severe cold climate or cold climate, hot summer/cold winter, and hot summer/warm winter), as well as one code for commercial buildings.[262] Urban residential and commercial codes are mandatory, whereas rural residential energy codes are voluntary.[263] In 2006, China launched a green building labeling system, the Three-Star Rating Building System,[264] which assigns ratings from one star to three stars according to criteria that include use of land, energy, and water, as well as material efficiency, indoor environmental quality, and operational management.[265] In addition to building design, the Three-Star Rating Building System measures performance and awards a rating after one year of a building's operation.[266]

**Figure 6-9. Buildings energy consumption in China, 1998–2012 (quadrillion Btu)**




China's first minimum energy performance standards for products such as refrigerators, room air conditioners, clothes washers, and televisions were adopted in 1989. Since then, additional minimum energy performance standards have been implemented for other major appliances, lighting, and cooling and heating equipment.[267] In 1998, China launched a voluntary energy efficiency labeling program, similar to the U.S. Energy Star program.[268] In 2005, the government introduced a mandatory energy information label, similar to the European Union's categorical energy label, with appliances categorized according to their levels of energy efficiency performance.[269]

The Chinese government has paid particular attention to retrofits and renovations of existing buildings,[270] with the goal of bringing existing buildings up to the level of code required for new construction. In 2011, the government strengthened its obligation by requiring a 10% reduction in energy consumption per square meter for commercial buildings and a 15% reduction for large commercial buildings with more than 20,000 square meters of floor area by the end of 2015. Under

*(continued on page 106)*

[261]S. Yu, M. Evans, and Q. Shi, *Analysis of the Chinese Market for Building Energy Efficiency*, PNNL-22761 (Pacific Northwest National Laboratory, Richland, WA, March 2014), http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22761.pdf.

[262]Berkeley Lab, China climate zone map, in "Cool Roofs in China Can Save Energy and Reduce Emissions" (Berkeley, CA, August 2014), http://newscenter.lbl.gov/2014/08/27/cool-roofs-in-china-can-save-energy-and-reduce-emissions/.

[263]M. Evans, B. Shui, M.A. Halverson, and A. Delgado, *Enforcing Building Energy Codes in China: Progress and Comparative Lessons*, PNNL-19247 (Pacific Northwest National Laboratory, Richland, WA, August 2010), http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19247.pdf.

[264]Institute for Building Efficiency, "Green Building Rating Systems: China" (Fact Sheet, September 2013), http://www.institutebe.com/InstituteBE/media/Library/Resources/Green%20Buildings/Fact-Sheet_Green-Building-Ratings_China.pdf.

[265]N. Khanna, J. Romankiewicz, W. Feng, N. Zhou, and Q. Ye, *Comparative Policy Study for Green Buildings in U.S. and China*, LBNL-6609E (Lawrence Berkeley National Laboratory, Berkeley, CA, April 2014), https://china.lbl.gov/sites/all/files/green_buildings_policy_comparison.pdf.

[266]Institute for Building Efficiency, "Efficient Buildings in China: Tough Policies Target Major Gains" (September 2010), http://www.institutebe.com/energy-policy/Efficient-Buildings-in-China.aspx.

[267]N. Zhou, N.Z. Khanna, D. Fridley, and J. Romankiewicz, *Development and implementation of energy efficiency standards and labeling programs in China: Progress and challenges*, LBNL-6141E (Lawrence Berkeley National Laboratory, Berkeley, CA, January 2013), https://china.lbl.gov/sites/all/files/china_sl_info.pdf.

[268]N. Zhou, *Status of China's Energy Efficiency Standards and Labels for Appliances and International Collaboration*, LBNL-251E (Lawrence Berkeley National Laboratory, Berkeley, CA, March 2008), https://china.lbl.gov/sites/all/files/china_sl_info.pdf.

[269]CLASP Publication Library, "Survey Evaluates China's $4.26 billion Subsidy Program for Energy Efficient Appliances" (November 2013), http://clasp.ngo/Resources/Resources/PublicationLibrary/2013/Survey_Evaluates_Chinas_4-26_billion_Subsidy_Program_for_Energy_Efficient_Appliances.

[270]Institute for Building Efficiency, "Efficient Buildings in China: Tough Policies Target Major Gains" (September 2010), http://www.institutebe.com/energy-policy/Efficient-Buildings-in-China.aspx.

the Green Building Action Plan of 2013, more than 400 million square feet in residential homes were to be retrofitted by the end of 2015, and all eligible commercial buildings in the northern heating zone were to be retrofitted by the end of 2020.[271]

Energy demand from China's buildings is expected to continue to grow as a result of urbanization, further increases in disposable income per capita, and demand for more comforts and services. Upgrades of building energy efficiency performance standards, new technology development, education and awareness programs, enforcement of energy efficiency policies, and improved compliance could each play a role in reducing future rates of growth in China's energy consumption.

In the IEO2016 Reference case, India's residential sector fuel mix transitions from mainly liquid fuels to mainly electricity. Electricity is used mostly for appliances; in 2010 ceiling fans and lighting accounted for nearly 62% of India's total residential electricity consumption, and refrigeration accounted for 13%.[272] As incomes increase and more people have access to electricity, the ownership of appliances powered by electricity also increases.[273] Consequently, electricity demand grows faster than total residential energy demand over the projection period: 5.5%/year compared with 3.2%/year.

### *Non-OECD Europe and Eurasia*

Russia is the largest economy in non-OECD Europe and Eurasia. In the IEO2016 Reference case, Russia's residential sector energy consumption grows by an average of 0.6%/year and accounts for about 50% of the region's total residential energy consumption in 2040. Although its population is expected to decline by an average of 0.4%/year from 2012 to 2040, increases in urbanization and GDP growth of about 2.0%/year contribute to an increase in Russia's residential energy use over that period.[274]

On a per capita basis, Russia currently leads the non-OECD countries in residential energy consumption, and its residential sector total continues to grow in the IEO2016 Reference case by 0.6%/year. Inefficient building designs and heating systems, along with the cold climate in much of Russia, are among the factors leading to high per capita energy consumption.[275] To improve the energy efficiency of residential buildings, the Russian government passed an Energy Efficiency Law in November 2009 that included mandated metering in new buildings, as well as other measures aimed at measuring building efficiency.[276] Although the IEO2016 Reference case assumes some improvements in Russia's energy efficiency, economic growth of 2.0%/year over the projection period results in rising living standards and more demand for energy-consuming appliances and equipment, offsetting some of the savings and resulting in increased residential energy use through 2040.

### *Other non-OECD*

The countries of the Middle East accounted for about 6.6% of total world residential energy consumption in 2012. The region's population accounted for 3.0% of the 2012 world total, but it is projected to grow by an average of 1.7%/year—far greater than the world average population increase of 0.9%/year. Although there are wide variations in income among the countries of the Middle East, the region's overall economy is projected to grow by 3.7%/year from 2012 to 2040 in the IEO2016 Reference case. Residential energy consumption in the region increases by an average of 1.9%/year in the Reference case. In the residential sector, electricity becomes the main source of energy, as its share of the fuel mix increases from 36% to 53% while the natural gas share declines from 44% to 34%. The increase in electricity results largely from higher demand for electric appliances, particularly air conditioners for space cooling.

Residential energy consumption in Africa increases by 2.2%/year from 2012 to 2040 in the Reference case. Much of the continent is still not connected to a power grid, relying heavily on traditional nonmarketed biomass as an energy source. In 2012, Africa accounted for about 15% of world population but only 3.5% of world marketed residential energy consumption. In the Reference case in 2040, Africa's share of world population rises to 21%, and its share of residential energy consumption rises to 4.3%. Energy consumption per capita is low in the region and is projected to remain nearly flat through 2040. Africa has the second-highest projected rate of GDP growth in the world in the IEO2016 Reference case, averaging 4.8%/year from 2012 to 2040.

In Brazil, the largest economy in the non-OECD Americas region, residential energy consumption increases by 1.6%/year from 2012 to 2040 in the Reference case. Brazil's household fuel mix continues to move away from liquid fuels toward electricity, and electricity remains the leading source of energy, followed by liquid fuels, throughout the projection period. Electricity's share of residential sector energy consumption grows from 61% in 2012 to 75% in 2040, while the liquid fuels share declines by more than one-third, from 37% to 24% over that period.

[271] S. Yu, M. Evans, and Q. Shi, *Analysis of the Chinese Market for Building Energy Efficiency*, PNNL-22761 (Pacific Northwest National Laboratory, Richland, WA, March 2014), http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22761.pdf.

[272] R. Rawal and Y. Shukla, *Residential Buildings in India: Energy Use Projections and Savings Potentials* (Global Buildings Performance Network, Paris, France, September 2014), p. 16, http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low.pdf.

[273] S. de la Rue du Can, et al., *Residential and Transportation Energy Use in India: Past Trend and Future Outlook* (Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory, January 2009), http://eetd.lbl.gov/sites/all/files/lbnl-1753e.pdf.

[274] Asia Pacific Energy Research Centre, *APEC Energy Demand and Supply Outlook 2006: Economy Review* (Japan: Institute of Energy Economics, 2006), pp. 79-84, http://aperc.ieej.or.jp/file/2010/9/24/EDSO2006_Whole_Report.pdf.

[275] T. Lychuk, M. Evans, M. Halverson, and V. Roshchanka, *Analysis of the Russian Market for Building Energy Efficiency*, PNNL-22110 (Richland, WA: Pacific Northwest National Laboratory, December 2012) p. 2, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22110.pdf.

[276] K.V. Bruk, "Energy Efficiency Laws in Russia – Starting the Journey," *The Moscow Times* (April 10, 2012), http://www.themoscowtimes.com/article/energy-efficiency-laws-in-russia--starting-the-journey/456427.html.

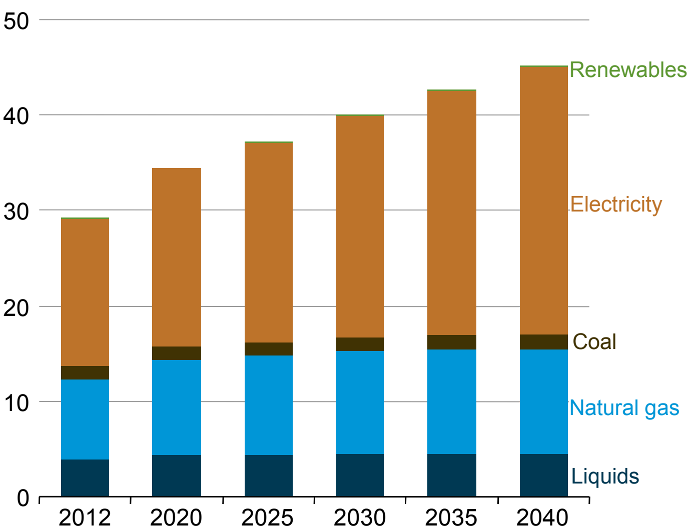
## Commercial sector

Commercial energy consumption occurs in profit-seeking and nonprofit enterprises engaged in commercial-scale activity (often called the service sector); energy is consumed by heating and cooling systems, lights, refrigerators, computers, and other equipment in the buildings where businesses, institutions, and other organizations are located. Examples of commercial sector buildings include retail stores, office buildings, government buildings, restaurants, hotels, schools, hospitals, and leisure and recreational facilities. Some nonbuilding energy use is included in the commercial sector, where it contributes to public services such as traffic lights and water and sewer systems. In the IEO2016 Reference case, total world delivered commercial sector energy consumption grows by an average of 1.6%/year from 2012 to 2040 and is the fastest-growing energy demand sector (Table 6-1).

In the IEO2016 Reference case, the rate of increase in non-OECD commercial sector energy use is twice the rate for the more mature energy-consuming economies of the OECD. Generally, the need for commercial enterprises (health, education, leisure, and government, among others) increases as populations, economies, and incomes grow, and non-OECD growth outpaces OECD growth in those categories. The combined non-OECD region accounted for more than 82% of the world's population in 2012, and its projected population growth rate is more than twice that of the OECD through 2040. In 2012, non-OECD countries accounted for about 53% of the world's GDP (measured in 2010 U.S. dollars on a purchasing power parity basis), and their combined rate of economic growth is more than twice that of the OECD throughout the projection.

In addition to economic and population growth trends, commercial delivered energy consumption is also affected by other economic measures, including employment rates, productivity, working conditions (such as those related to the health, safety, and comfort of workers), and the amount of economic activity occurring in commercial enterprises (as opposed to other end-use demand sectors, such as the industrial sector). Commercial energy consumption is determined by other factors as well, including climate, availability of resources and technology, and the efficiency of buildings and equipment. Although the energy efficiencies of building shells and commercial equipment typically are determined by management decisions during the construction of buildings and operation of commercial enterprises, those decisions also can be influenced by national energy policies and laws. Throughout the world, electricity is increasingly the preferred energy source in the commercial sector (Figure 6-10). Electricity accounted for about 53% of world commercial energy use in 2012, and its share grows to 62% in 2040 in the IEO2016 Reference case. Electricity and natural gas remain the most prominent fuels in the commercial sector, together accounting for about 81% of total world delivered energy in 2012 and 86% in 2040.

**Figure 6-10. World commercial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**




### *OECD commercial energy consumption*

Overall, the OECD economies use more energy in their commercial sectors than do the non-OECD economies. In 2012 OECD commercial energy use was 116% greater than

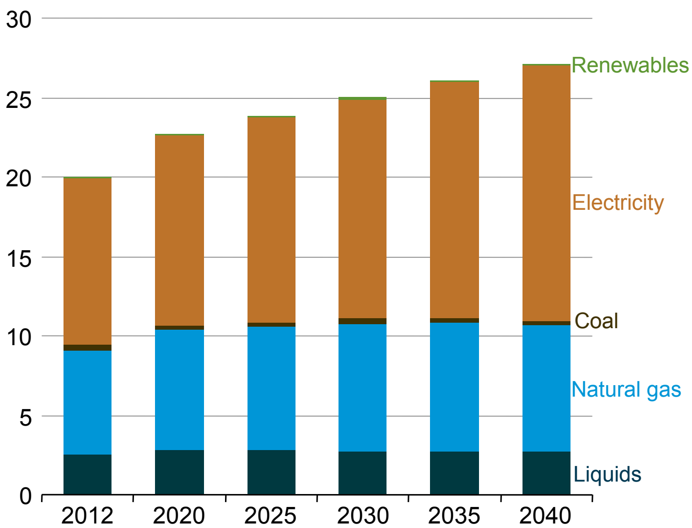
**Table 6-1. Annual average percent change in commercial sector delivered energy consumption by region (percent per year)**

| Region | Average annual percent change 2012–20 | 2020–30 | 2030–40 | 2012–40 |
|---|---|---|---|---|
| OECD | **1.6** | **0.9** | **0.8** | **1.1** |
| Americas | 1.1 | 0.8 | 1.0 | 0.9 |
| Europe | 1.9 | 1.2 | 0.8 | 1.3 |
| Asia | 2.4 | 0.9 | 0.6 | 1.2 |
| Non-OECD | **3.0** | **2.5** | **1.9** | **2.4** |
| Europe and Eurasia | 2.1 | 1.5 | 0.9 | 1.4 |
| Asia | 3.7 | 2.9 | 2.1 | 2.9 |
| Middle East | 2.4 | 2.5 | 2.0 | 2.3 |
| Africa | 3.3 | 3.1 | 3.1 | 3.2 |
| Americas | 2.1 | 1.9 | 1.7 | 1.9 |
| Total World | **2.1** | **1.5** | **1.2** | **1.6** |

non-OECD use, and in 2040 it remains 50% greater in the IEO2016 Reference case, despite considerably larger and more rapidly growing populations in the non-OECD countries. The total population of the non-OECD region was 4.7 times the OECD total in 2012, and it is 5.5 times the OECD total in 2040. With higher energy use and fewer people, the average person in the OECD region uses much more commercial energy than the average person in the non-OECD region. This difference reflects the fact that OECD economies are further along in switching from industrial activities to commercial sector service activities, as well as having higher incomes, productivity, and comfort for workers in OECD commercial enterprises than those in the non-OECD region. In 2012, OECD commercial energy use per person was 10.1 times higher than the non-OECD level, and it remains 8.3 times higher in 2040 in the IEO2016 Reference case.

The composition of the fuel mix in the OECD commercial sector follows world averages relatively closely, with electricity and natural gas being predominant (Figure 6-11). In 2012, electricity accounted for more than half of the region's total commercial energy use, and it is the fastest growing commercial energy source through 2040. Natural gas meets a significant amount of the remaining share, accounting for about 33% of OECD commercial energy use in 2012 and 30% in 2040. Together, electricity and natural gas provide between 85% and 89% of OECD commercial energy use over the projection, with most of the remainder being provided by liquid fuels.

**Figure 6-11. OECD commercial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**




*OECD Americas*

The United States has the world's largest commercial sector energy use, correlated with its average per-capita income (measured as average GDP per person), which is among the world's highest. A large portion of U.S. economic activity is in the commercial sector. The Mexico/Chile region has the smallest amount of commercial energy consumption among the OECD regions but the fastest growth in commercial energy use from 2012 to 2040. Mexico/Chile also has the fastest-growing GDP per capita among the OECD regions in the IEO2016 Reference case (Figure 6-12).

Among the OECD countries, the United States has the second-slowest growth rate in commercial energy use from 2012 to 2040, after Japan (Figure 6-13). The relatively slow increase in U.S. commercial energy use is partially a result of federal efficiency standards, which foster technological improvements in end-use equipment and act to limit growth in delivered energy consumption relative to growth in commercial floorspace.[277] Efficiency improvements in the United States are expected for lighting, refrigeration, space

**Figure 6-12. Average annual change in OECD GDP per capita, 2012–40 (percent per year)**

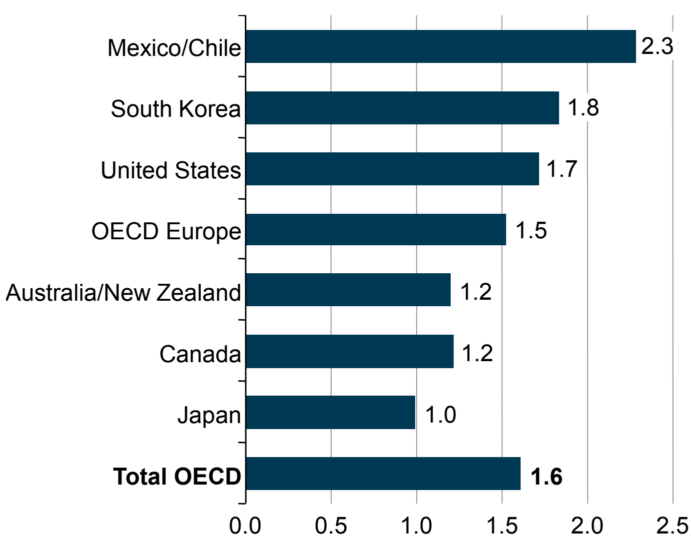
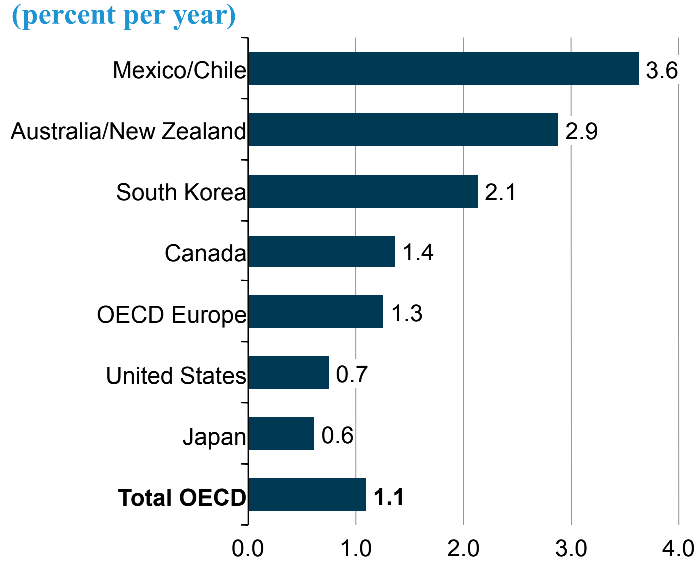



**Figure 6-13. Average annual change in OECD commercial sector energy consumption, 2012–40 (percent per year)**




[277]U.S. Energy Information Administration, *Annual Energy Outlook 2013*, DOE/EIA-0383(2013) (Washington, DC: April 2013), pp. 63-64, http://www.eia.gov/forecasts/archive/aeo13/pdf/0383(2013).pdf.

cooling, and space heating as a result of the Energy Independence and Security Act of 2007 (EISA2007) and the Energy Policy Act of 2005.

### *OECD Europe*

Commercial sector energy use in OECD Europe increases by 1.3%/year in the IEO2016 Reference case. OECD Europe has an established history of efficiency initiatives and, among OECD regions, used the lowest amount of energy per unit of economic output (GDP) in 2012. The October 2012 enactment of the European Union's Energy Efficiency Directive improves energy efficiency in the buildings sector.[278] In addition, a number of individual countries in OECD Europe have introduced initiatives to improve energy efficiency in the commercial sector. For example, the Netherlands strengthened its building standards in 2009, requiring newly constructed or renovated nonresidential buildings to be 40% more energy-efficient than previous standards.[279]

### *OECD Asia*

OECD Asia is a dynamic region that features economies at different stages of commercial sector development. Japan has a large commercial sector and high energy use per capita, whereas South Korea and Australia/New Zealand have smaller commercial sectors that are growing rapidly. In 2012, Japan had the highest ratio of commercial energy use to industrial energy use in the world, slightly higher than that of the United States (Figure 6-14). Although this ratio remains fairly flat in the United States, the ratio in Japan continues to grow through 2040, both because of increased energy efficiency in U.S. commercial enterprises and because of more growth in industrial sector output than in Japan. In 2012, Mexico/Chile had the lowest ratio of commercial-to-industrial-sector energy use of any OECD region, followed by Australia/New Zealand and South Korea.

Economies in the OECD Asia region have much higher shares of service and commercial-scale activity than those in non-OECD Asia: commercial energy use grows from 13% to 16% of total delivered energy use in OECD Asia from 2012 to 2040, while in non-OECD Asia it grows from 3% to 4%. In addition, the OECD Asia countries have much higher energy use per capita and higher incomes. In 2012, average GDP per capita was 4.6 times higher in OECD Asia than in non-OECD Asia. Average GDP per capita remains higher in OECD Asia through 2040, but it grows more slowly and in 2040 is only 2.2 times higher than non-OECD Asia GDP per capita.

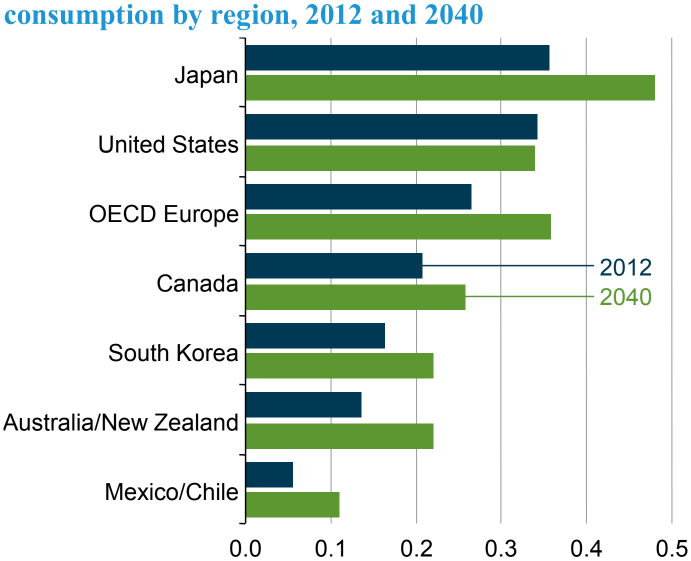
The commercial sectors of OECD Asia are modern in terms of fuel use. Through the entire projection, Australia/New Zealand and South Korea use higher proportions of electricity than the average OECD commercial sector. In Japan, 44% to 48% of commercial sector energy demand is met by electricity (slightly less than the OECD average) in the projection, and the remainder is met about equally by natural gas and liquid fuels. Although liquid fuels use grows slightly in South Korea through 2040, most new commercial demand in OECD Asia is met by electricity and natural gas.

## *Non-OECD commercial energy consumption*

Non-OECD commercial energy consumption remains lower than in the OECD throughout the projection, but it increases at twice the rate of OECD commercial sector energy use. Non-OECD GDP and GDP per capita also increase by more than twice the rate in the OECD. Even in 2040, average GDP per capita in the OECD countries is about 2.7 times that in the non-OECD countries. Non-OECD Asia and Africa have the fastest projected growth in commercial energy consumption among the non-OECD regions in the IEO2016 Reference case (Figure 6-15).

The country with the highest commercial energy use in the non-OECD region throughout the projection is China, although India's commercial energy consumption grows fastest. Incomes, measured as average GDP per capita, also rise the fastest in the non-OECD Asia region, with India leading the growth (Figure 6-16). Rising incomes allow for increasing demand for commercial services and for greater productivity and comfort in commercial buildings and work spaces. Although the OECD countries maintain higher levels of commercial services in proportion to total economic activity, the non-OECD countries are gradually closing the gap. Russia has the slowest growth in commercial energy use in the non-OECD region from 2012 to 2040, mostly because it has the slowest economic growth in the region, and a declining population. (Russia and Japan are the only regions with declining populations out to 2040.)

**Figure 6-14. Ratio of OECD commercial sector energy consumption to industrial sector energy consumption by region, 2012 and 2040**




[278]European Commission, "Energy Efficiency: Energy Efficiency Directive," http://ec.europa.eu/energy/efficiency/eed/eed_en.htm.

[279]N. Betlem, H. van Eck, R. Beuken, M. Heinemans, and L. van Diggelen, "Implementation of the EPBD in The Netherlands: Status in November 2010" (European Union, 2011), http://www.epbd-ca.org/Medias/Pdf/country_reports_14-04-2011/The_Netherlands.pdf.

On average, electricity accounted for 53% of non-OECD commercial sector fuel use in 2012, and its share is expected to continue growing to 67% in 2040 (Figure 6-17). Natural gas, coal, and liquid fuels accounted for relatively equal shares of non-OECD commercial sector fuel use in 2012. From 2012 to 2040, the coal and liquid fuels shares decline more rapidly. Electricity and natural gas combined accounted for 73% of non-OECD commercial energy use in 2012; in 2040, they account for 83%, with coal's share declining from 12% in 2012 to 7% in 2040. Still, electricity and natural gas combined in the non-OECD account for a lower share of commercial sector energy consumption than in the OECD in 2040.

### *Non-OECD Asia*

Growth in productivity and incomes continues to drive economic development in non-OECD Asia, making it the region with the most new commercial energy demand. From 2012 to 2040, China adds the most new commercial energy use of any individual country in the world (2.4 quadrillion Btu), and India experiences the fastest growth in commercial energy use (3.7%/year). India also has the highest economic growth in the world through 2040 and surpasses China as the most populous country in 2028. As a region, Africa's commercial sector energy consumption grows faster than non-OECD Asia's, but non-OECD Asia has a much larger commercial sector and adds more new energy use over the projection.

In the Reference case, output per capita for commercial sector enterprises grows fastest in the Middle East, followed by China and India. However, fuel use in the Middle East, including commercial energy use, is less efficient than in China and India. In addition, per capita output in the industrial sector grows faster in China and India than in the rest of the world. Accordingly, China and India have the fastest growth in GDP per capita in the world (see Figure 6-16) and strong growth in commercial sector energy use. As in the OECD countries, electricity accounts for the most commercial energy use in non-OECD Asia and is the region's fastest-growing commercial sector energy source. Unlike in the OECD, most of the rest of commercial energy use in non-OECD Asia consists of liquid fuels and coal, particularly in China. The natural gas share of non-OECD Asia's commercial energy use remains relatively low, at about 10% from 2012 to 2040.

### *Other non-OECD*

Non-OECD Europe and Eurasia and the Middle East are among the few non-OECD regions that have relatively high shares of natural gas use in their commercial sectors, with at least a 20% share of commercial energy fuel mix at some point in the projection. In non-OECD Europe and Eurasia, natural gas accounted for 45% of the commercial energy mix in 2012 and remains the sector's predominant fuel through 2038.

**Figure 6-15. Average annual change in non-OECD commercial sector energy consumption, 2012–40 (percent per year)**

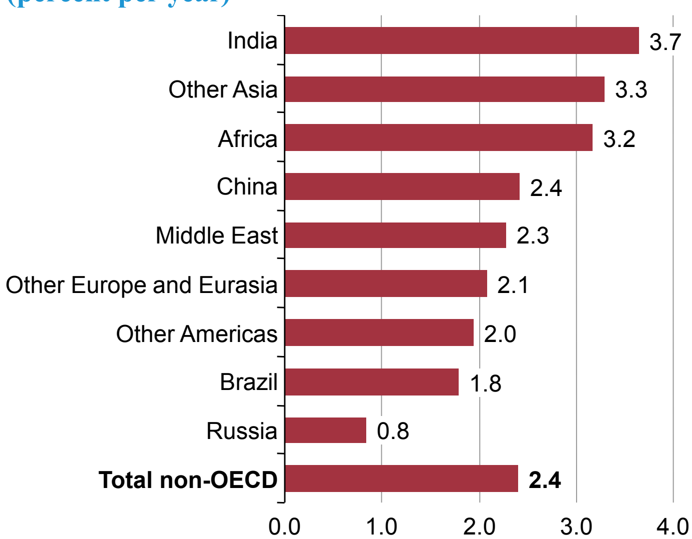



**Figure 6-16. Average annual change in non-OECD GDP per capita, 2012–40 (percent per year)**

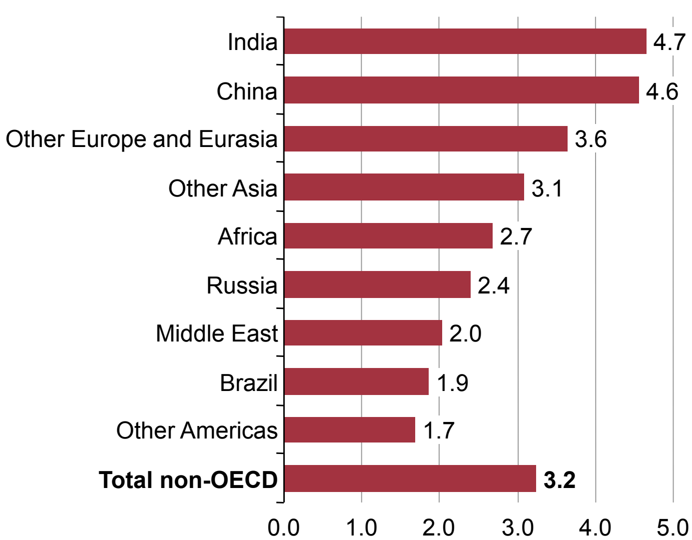
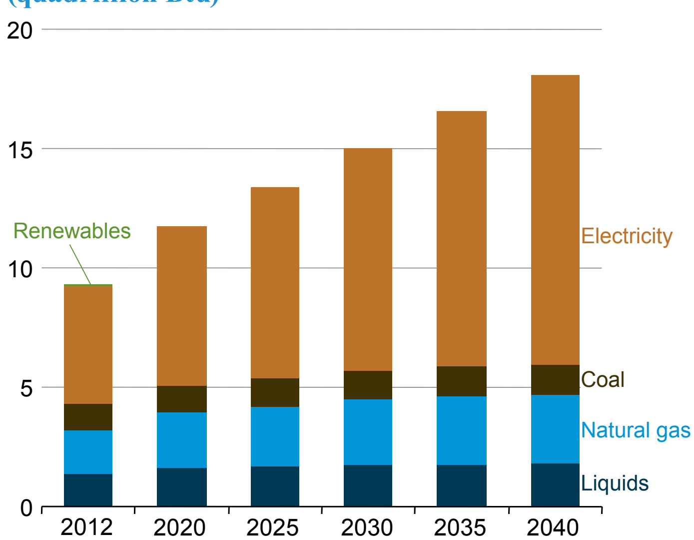



**Figure 6-17. Non-OECD commercial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**



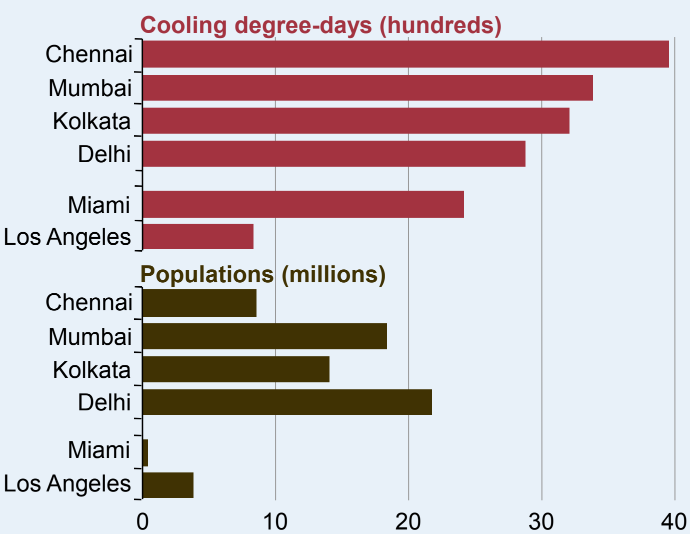
In Brazil, commercial sector energy use is dominated by electricity, which accounted for 92% of the country's commercial energy use in 2012 and will account for 93% in 2040 in the Reference case. However, as a result of concern about overreliance on electricity in the aftermath of a severe drought that resulted in electricity shortages and a national energy emergency, the Brazilian government in 2001 enacted a Law of Energy Efficiency[280] and in 2009 released energy efficiency rules for commercial buildings in an effort to improve energy efficiency. The goal of the 2009 initiative is to manage growth in energy consumption through improvements in commercial building shells, heating and cooling systems, and lighting.

## Electricity demand for space cooling in India

In India and other developing countries around the world, rising incomes and a natural preference for comfortable indoor air temperatures are resulting in rapid growth of energy use for space cooling. The two most prevalent cooling technologies for buildings are fans and air conditioners, with air conditioners using much more energy. Currently, the penetration of air-conditioning technologies in India is relatively low compared with the United States and other developed countries. The most recent data from EIA's Residential Energy Consumption Survey (RECS) show that 87% of U.S. households have air-conditioning equipment,[281] compared with 2% of India's households.[282] The estimated U.S. total of about 114 million household air-conditioning units accounts for 186 billion kilowatthours (kWh) of electricity demand annually. India's total of about 28 million household air-conditioning units includes 3.3 million units sold in fiscal year 2013–14.[283] These numbers suggest the potential for significant growth in India's demand for air conditioning and energy consumption for space cooling.

According to a recent estimate, global energy demand for air conditioning would be about 50 times higher if all countries around the world adopted space cooling habits comparable to those in the United States.[284] According to this estimate, India has the most growth potential, with a potential market for air conditioning that is 14 times the size of the U.S. market, given India's warmer, wetter climate (Figure 6-18) and larger population. India's middle class is expected to grow to 53.3 million households by the end of 2015 and to 113.8 million households by the end of 2025.[285]

**Figure 6-18. Estimated cooling degree days per year and populations in selected Indian and U.S. cities, 2011**




People in the developing world, and particularly in India, are using their growing incomes to purchase air conditioners and other energy-using equipment to improve their living standards. In recent years, sales of air conditioners in India increased by 20% annually,[286] and a recent major market study estimates that the market for air conditioners in India will grow by 10%/year from 2015 to 2020.[287] Room air conditioners—portable units that can stand in a room or be installed in a window—currently dominate India's market for air conditioning, and their dominance is expected to continue in the future.

Issues of air-conditioning demand come under more scrutiny when power providers and other institutional stakeholders discuss energy planning for peak demand hours and the added pressures of summer heat waves. During the summer of 2012, India's power generation experienced a shortfall in meeting peak demand by about 17 gigawatts, leading to

*(continued on page 112)*

[280] C. Naves, D. Amorim, et al., "Energy efficiency code in Brazil: Experiences in the first public building labeled in Brasilia," in *Proceedings of the Fourth National Conference of IBPSA-USA* (New York, NY: August 11-13, 2010), pp. 352-357.

[281] U.S. Energy Information Administration, "Air conditioning in nearly 100 million U.S. homes," *2009 Residential Energy Consumption Survey*, http://www.eia.gov/consumption/residential/reports/2009/air-conditioning.cfm.

[282] M. Sivak, "Will AC Put a Chill on the Global Energy Supply?" *American Scientist*, Vol. 101, No. 5 (September-October 2013), p. 330, http://www.americanscientist.org/issues/pub/2013/5/will-ac-put-a-chill-on-the-global-energy-supply/1.

[283] Research and Markets, "Opportunities in the Indian Air Conditioner Market" (December 2014), http://www.researchandmarkets.com/reports/3058379/opportunities-in-the-indian-air-conditioner-market.

[284] M. Sivak, "Will AC Put a Chill on the Global Energy Supply?" *American Scientist*, Vol. 101, No. 5 (September-October 2013), p. 330, http://www.americanscientist.org/issues/pub/2013/5/will-ac-put-a-chill-on-the-global-energy-supply/1. The study normalized for cooling degree days (CDD) but not for other factors, such as dwelling characteristics and aspects of climate other than temperature (for example, cloud cover and humidity).

[285] S. Chidanamarri, "Air Conditioners Market in India" (Frost & Sullivan, March 18, 2013), https://www.frost.com/sublib/display-market-insight.do?id=275489972.

[286] M. Sivak, "Will AC Put a Chill on the Global Energy Supply?" *American Scientist*, Vol. 101, No. 5 (September-October 2013), p. 330, http://www.americanscientist.org/issues/pub/2013/5/will-ac-put-a-chill-on-the-global-energy-supply/1.

[287] TechSci Research, *India Air Conditioners Market Forecast and Opportunities, 2020* (June 2015), http://www.reportlinker.com/p0881690-summary/India-Air-Conditioners-Market-Forecast-Opportunities.html.

interruptions of residential electricity service for 16 hours a day in some areas of the country[288] and a large-scale blackout that affected nearly 600 million people.[289] In 2015, India experienced an intense and sustained heat wave, setting records in many parts of the country (heat indexes registered as high as 144 degrees Fahrenheit in Bhubneshwar, close to the northeast coast of India).[290] While there is still much to learn about the performance of the power grid during the 2015 heat wave, there have been reported improvements in procedures since 2012 and also reports of electricity outages that lasted four hours a day in the northern region of the country.[291]

India began its first efficiency program for air conditioners in 2006, when India's Bureau of Energy Efficiency (BEE) started a standards and competitive labeling program for the equipment. The program involves setting a standard minimum efficiency level, with a competitive labeling program above that level, so consumers can compare higher efficiency levels when purchasing air conditioners. BEE also set out a plan to raise the minimum standard and corresponding competitive labels over time. An early analysis of the program by Lawrence Berkeley National Laboratory (LBNL) estimated that the standards and labels would reduce electricity use by 27 terawatthours (TWh) annually by 2020, projecting base case consumption of 42 TWh in 2010, 195 TWh in 2020, and 552 TWh in 2030 for air conditioning alone without the efficiency program.[292] Subsequent LBNL analysis has shown that the expected increase in the minimum efficiency level has been delayed compared to the earlier analysis, which assumed a minimum standard of 2.7 Energy Efficiency Ratio (EER) by 2010 (a level that was not actually reached until 2014).[293] As the country's market for air conditioning grows and pushes up energy use, efforts to increase efficiency can help relieve the upward pressure on electricity demand.

[288] S. Cox, "Cooling a Warming Planet: A Global Air Conditioning Surge," *Yale Environment 360* (July 10, 2012), http://e360.yale.edu/feature/cooling_a_warming_planet_a_global_air_conditioning_surge/2550/.

[289] *Hindustan Times*, "Heatwave claims over 1,100 across country, temperatures soaring" (May 28, 2015), http://www.hindustantimes.com/india-news/heat-wave-claims-over-750-lives-in-ap-telangana-temperatures-will-continue-to-soar-this-week/article1-1351358.aspx.

[290] J. Samenow, "India's hellish heat wave, in hindsight," *The Washington Post* (June 10, 2015), http://www.washingtonpost.com/blogs/capital-weather-gang/wp/2015/06/10/indias-hellish-heat-wave-in-hindsight/.

[291] *Hindustan Times*, "India's electricity woes: The heat's on, the power's off" (May 25, 2015), http://www.hindustantimes.com/comment/india-s-electricity-woes-the-heat-s-on-the-power-s-off/article1-1351170.aspx.

[292] M.A. McNeil and M. Iyer, *Techno-Economic Analysis of Indian Draft Standard Levels for Room Air Conditioners*, LBNL-64204 (Lawrence Berkeley National Laboratory, Berkeley, CA, March 2007), https://escholarship.org/uc/item/8wr8433w#page-1.

[293] A. Phadke, N. Abhyankar, and N. Shah, *Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges* (Lawrence Berkeley National Laboratory, Berkeley, CA, June 2014), http://eetd.lbl.gov/sites/all/files/lbnl-6674e.pdf.

## Chapter 7
# Industrial sector energy consumption

## Overview

The industrial sector uses more delivered energy[294] than any other end-use sector, consuming about 54% of the world's total delivered energy. The industrial sector can be categorized by three distinct industry types: energy-intensive manufacturing, nonenergy-intensive manufacturing, and nonmanufacturing (Table 7-1). The mix and intensity of fuels consumed in the industrial sector vary across regions and countries, depending on the level and mix of economic activity and on technological development. Energy is used in the industrial sector for a wide range of purposes, such as process and assembly, steam and cogeneration, process heating and cooling, and lighting, heating, and air conditioning for buildings. Industrial sector energy consumption also includes basic chemical feedstocks. Natural gas feedstocks are used to produce agricultural chemicals. Natural gas liquids (NGL) and petroleum products (such as naphtha) are both used for the manufacture of organic chemicals and plastics, among other uses.

In the *International Energy Outlook 2016* (IEO2016) Reference case, worldwide industrial sector energy consumption is projected to increase by an average of 1.2%/year, from 222 quadrillion British thermal units (Btu) in 2012 to 309 quadrillion Btu in 2040 (Table 7-2). Most of the long-term growth in industrial sector delivered energy consumption occurs in countries outside of the Organization for Economic Cooperation and Development (OECD). From 2012 to 2040, industrial energy consumption in non-OECD countries grows by an average of 1.5%/year, compared with 0.5%/year in OECD countries. Non-OECD industrial energy consumption, which accounted for 67% of world industrial sector delivered energy in 2012, accounts for 73% of world industrial sector delivered energy consumption in 2040.

Overall, total industrial sector energy use increases from 73 quadrillion Btu in 2012 to 85 quadrillion Btu in 2040 in the OECD countries, and from 149 quadrillion Btu in 2012 to 225 quadrillion Btu in 2040 in the non-OECD countries. OECD industrial sector energy use grows slowly in the IEO2016 Reference case, averaging 0.5%/year from 2012 to 2040. The industrial sector accounts for approximately 40% of total OECD delivered energy use from 2012 to 2040. In the non-OECD industrial sector, the share of delivered energy use declines from 64% in 2012 to 59% in 2040, as many emerging non-OECD economies move away from energy-intensive manufacturing, while energy use grows more rapidly in all other end-use sectors.

### Table 7-1. World industrial sector: major groupings and representative industries

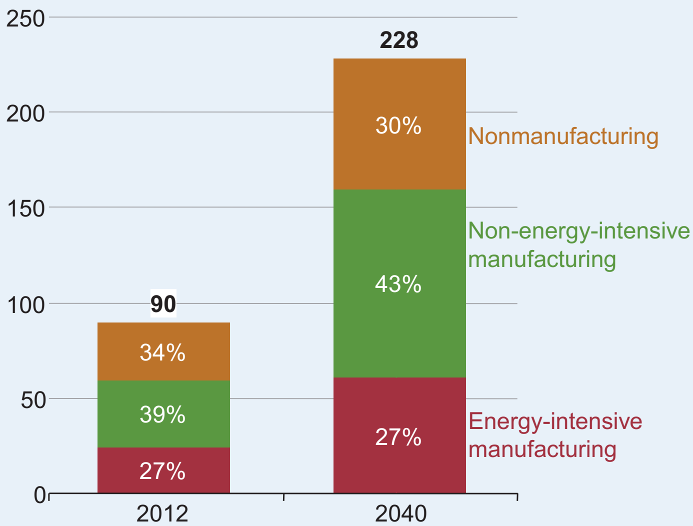
| Industry grouping | Representative industries |
|---|---|
| **Energy-intensive manufacturing** | |
| Food | Food, beverage, and tobacco product manufacturing |
| Pulp and paper | Paper manufacturing, printing and related support activities |
| Basic chemicals | Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals; includes chemical feedstocks |
| Refining | Petroleum refineries and coal products manufacturing, including coal and natural gas used as feedstocks |
| Iron and steel | Iron and steel manufacturing, including coke ovens |
| Nonferrous metals | Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin |
| Nonmetallic minerals | Primarily cement and other nonmetallic minerals, such as glass, lime, gypsum, and clay products |
| **Nonenergy-intensive manufacturing** | |
| Other chemicals | Pharmaceuticals (medicinal and botanical), paint and coatings, adhesives, detergents, and other miscellaneous chemical products, including chemical feedstocks |
| Other industrials | All other industrial manufacturing, including metal-based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment) |
| **Nonmanufacturing** | |
| Agriculture, forestry, fishing | Agriculture, forestry, and fishing |
| Mining | Coal mining, oil and natural gas extraction, and mining of metallic and nonmetallic minerals |
| Construction | Construction of buildings (residential and commercial), heavy and civil engineering construction, industrial construction, and specialty trade contractors |

[294] Delivered energy is measured as the heat content of energy at the site of use. It includes the heat content of electricity (3,412 Btu/kWh) but does not include conversion losses at generation plants in the electricity sector. Delivered energy also includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

## Regional gross output and industrial energy consumption

In the IEO2016 Reference case, real inflation-adjusted gross output is used to estimate industrial sector energy consumption by disaggregating economic activity into sectors and industries. Gross output includes intermediate inputs such as energy, materials, and purchased services used in production processes, providing data on all industry links that make up economic activity. In contrast, gross domestic product (GDP) and its components—which are value-added concepts—do not include intermediate inputs to industrial processes. In the IEO2016 projections, analysis of the key components of industrial gross output and how they change over time helps to explain regional changes in industrial sector energy consumption.

**Figure 7-1. Global gross output by industrial subsector, 2012 and 2040 (trillion 2010 dollars)**




Total gross output includes all economic activity, while industrial energy use includes three subsectors: nonmanufacturing, energy-intensive manufacturing, and nonenergy-intensive manufacturing (Table 7-3).[295] The shares of the gross output sectors vary by region and over time. Worldwide, gross output from the services sector increases by 3.5%/year from 2012 to 2040 in the IEO2016 Reference case, and energy-intensive manufacturing increases at a similar rate of 3.4%/year. In contrast, gross output from the nonmanufacturing sector grows at a slower rate of 2.9%/year. The fastest growth is projected for the nonenergy-intensive manufacturing sector, at 3.9%/year. This results in a long-term shift in the composition of gross output in the IEO2016 Reference case (Figure 7-1), showing a general long-term trend toward a worldwide economy that is slightly less dependent on agricultural and mined natural resources—two of the three nonmanufacturing industries. A move away from resource-based or agriculture-based national output, which has long been observed in the developed economies, is anticipated in the long-term outlook for the world's emerging economies.

*(continued on page 115)*

**Table 7-2. World industrial sector delivered energy consumption by region and energy source, 2012–40 (quadrillion Btu)**

| Energy source by region | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| OECD | **73.3** | **77.6** | **80.0** | **81.7** | **83.0** | **84.6** | **0.5** |
| Liquid fuels | 27.2 | 28.9 | 29.8 | 30.3 | 30.4 | 30.6 | 0.4 |
| Natural gas | 21.0 | 22.7 | 23.4 | 24.2 | 24.9 | 25.7 | 0.7 |
| Coal | 8.5 | 8.7 | 8.8 | 8.9 | 9.0 | 9.0 | 0.2 |
| Electricity | 10.9 | 11.6 | 12.1 | 12.5 | 12.8 | 13.2 | 0.7 |
| Renewables | 5.7 | 5.7 | 5.8 | 5.9 | 5.9 | 6.1 | 0.3 |
| Non-OECD | **149.0** | **168.3** | **182.6** | **196.3** | **211.0** | **224.5** | **1.5** |
| Liquid fuels | 39.3 | 43.3 | 46.7 | 50.3 | 54.2 | 57.9 | 1.4 |
| Natural gas | 29.7 | 33.6 | 38.6 | 43.8 | 49.6 | 54.7 | 2.2 |
| Coal | 47.3 | 53.4 | 55.5 | 57.1 | 58.6 | 59.7 | 0.8 |
| Electricity | 21.0 | 25.5 | 27.9 | 29.7 | 31.5 | 33.1 | 1.6 |
| Renewables | 11.8 | 12.5 | 13.9 | 15.4 | 17.1 | 19.0 | 1.7 |
| Total World | **222.3** | **245.8** | **262.6** | **278.0** | **294.0** | **309.1** | **1.2** |
| Liquid fuels | 66.5 | 72.2 | 76.5 | 80.6 | 84.6 | 88.6 | 1.0 |
| Natural gas | 50.7 | 56.2 | 62.0 | 68.0 | 74.5 | 80.4 | 1.7 |
| Coal | 55.7 | 62.0 | 64.3 | 66.0 | 67.2 | 68.7 | 0.8 |
| Electricity | 31.9 | 37.2 | 40.0 | 42.2 | 44.3 | 46.3 | 1.3 |
| Renewables | 17.4 | 18.2 | 19.7 | 21.3 | 23.0 | 25.1 | 1.3 |

Note: Data on delivered industrial sector energy consumption do not include conversion losses at electricity sector generation plants. Delivered energy includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

[295] Details of the industries included in gross output, along with their NACE 2 codes, can be found in the IEO2016 macroeconomic documentation.

Globally, much of the slower growth in the nonmanufacturing sector is offset by increased growth in the services and nonenergy-intensive manufacturing sectors, whereas the energy-intensive manufacturing share of total gross output does not change. Many manufacturing industries are driven by trade. Some countries benefit from access to supply chains for technology goods; some benefit from competitive labor costs that lead to increases in nonenergy-intensive manufacturing production. Regional growth in the nonmanufacturing and services sectors differs according to the variety of industries that make up the sectors. In some regions, growth in the services sector is based on government spending, which is not necessarily linked to technological advances or access to markets. In other regions, growth in the nonmanufacturing sector is based on the availability of natural resources.

On a regional basis, the largest changes in industrial sector composition in the IEO2016 Reference case are projected for the Middle East and Russia (where mining/extraction is the largest component of the nonmanufacturing sector), and for India (where agriculture is currently the largest component of the nonmanufacturing sector) as a result of development and increasing standards of living, as well as changing fuel markets. In those regions, relatively rapid increases are projected for the services sector from 2012 to 2040, with all other gross output sectors, and particularly the nonmanufacturing sector, becoming smaller. For India, the shift toward services is explained by slower growth in the agriculture industry. For the Middle East and Russia, the shift is explained by slower growth in the oil and natural gas extraction industry.

For Mexico and Chile, there is a notable increase in the nonenergy-intensive manufacturing sector share of their combined economies. Although the IEO2016 projections do not include explicit calculations for the individual industries that make up the "other" industrial category, its largest component is transportation equipment. Growth in the transportation equipment industry is expected to account for much of the growth in both countries' nonenergy-intensive manufacturing sectors.

Both China and OECD Europe have declared goals to move away from heavy industry in the future. Although the IEO2016 Reference case does not show double-digit changes for its industrial sector, China remains one of the most influential economies in the world. The services sector share of China's economy increases in the Reference case, and growth in the nonmanufacturing and energy-intensive manufacturing sectors is slower than growth in the services sector. OECD Europe, which continues to account for the third-largest share of world gross output through 2040, shows a small shift away from the most energy-intensive industries over the projection period.

*(continued on page 116)*

### Table 7-3. Average annual growth in gross output by region and sector, 2012–40 (percent per year)

| | IEO2016 industrial sector activity | | | |
|---|---|---|---|---|
| Region | Energy-intensive manufacturing sector | Nonenergy-intensive manufacturing sector | Nonmanufacturing sector | Service sector/ rest of economy |
| OECD | **1.5** | **2.4** | **1.8** | **2.0** |
| OECD Americas | **2.0** | **3.5** | **2.5** | **2.5** |
| United States | 1.1 | 2.4 | 1.5 | 1.9 |
| Canada | 1.8 | 2.2 | 2.1 | 2.1 |
| Mexico/Chile | 3.2 | 4.2 | 2.2 | 3.2 |
| OECD Europe | **1.2** | **1.9** | **1.1** | **1.8** |
| OECD Asia | **1.2** | **1.5** | **1.4** | **1.4** |
| Japan | 0.0 | 0.4 | 0.2 | 0.7 |
| South Korea | 2.2 | 2.2 | 1.9 | 2.0 |
| Australia/New Zealand | 2.5 | 1.8 | 2.3 | 2.7 |
| Non-OECD | **4.1** | **4.6** | **3.3** | **4.9** |
| Non-OECD Europe and Eurasia | **2.3** | **2.2** | **0.8** | **3.4** |
| Russia | 2.3 | 1.8 | 0.2 | 3.4 |
| Other | 2.3 | 3.0 | 2.0 | 3.3 |
| Non-OECD Asia | **4.5** | **4.8** | **3.7** | **5.2** |
| China | 4.3 | 4.8 | 3.2 | 5.6 |
| India | 5.4 | 5.8 | 4.0 | 6.8 |
| Other | 4.0 | 4.0 | 4.2 | 3.8 |
| Middle East | **3.5** | **4.4** | **3.0** | **7.3** |
| Africa | **2.8** | **4.3** | **2.9** | **3.8** |
| Non-OECD Americas | **2.3** | **2.1** | **3.0** | **2.8** |
| Brazil | 2.4 | 1.8 | 3.0 | 2.5 |
| Other | 2.3 | 2.3 | 3.0 | 2.9 |
| Total World | **3.4** | **3.9** | **2.9** | **3.5** |

Within gross output sectors there is a shift in regional shares of total world production for individual industries. India gains a larger share of world nonmetallic mineral production, in part because of rapid growth in its domestic construction industry. India's share of world steel production also increases from 2012 to 2040, while China's share remains relatively flat. In the paper industry, China's share of world production increases as growth is slower in other regions, including in Russia and in other non-OECD Europe and Eurasia. For basic chemicals, the Middle East, China, and India have increasing production shares throughout the projection period. Finally, most non-OECD countries increase their shares of total world agricultural sector production through 2040, and most OECD countries have decreasing shares. Within gross output sectors there is a shift in regional shares of total world production for individual industries. India gains a larger share of world nonmetallic mineral production, in part because of rapid growth in its domestic construction industry. India's share of world steel production also increases from 2012 to 2040, while China's share remains relatively flat. In the paper industry, China's share of world production increases as growth is slower in other regions, including in Russia and in other non-OECD Europe and Eurasia. For basic chemicals, the Middle East, China, and India have increasing production shares throughout the projection period. Finally, most non-OECD countries increase their shares of total world agricultural sector production through 2040, and most OECD countries have decreasing shares.

Industrial sector delivered energy consumption varies by region, according to differences in industrial gross output, energy intensity (measured as energy consumed per unit of gross output), and the composition of industries. Enterprises are able to reduce energy consumption in a number of ways, including improving industrial sector processes to reduce energy waste and recover energy lost (often process heat), increasing the use of cogeneration, and recycling materials and fuel inputs to reduce costs and improve efficiency. In terms of industrial fuel use, natural gas and electricity are the fastest-growing forms of industrial energy use in the OECD region (Figure 7-2), with each energy source increasing by about 0.7%/year from 2012 to 2040. Consumption of liquids, coal, and renewable energy in the OECD industrial sector grows more slowly, averaging 0.4%/year (liquids), 0.3%/year (renewable energy), and 0.2%/year (coal). As a result, from 2012 to 2040, the natural gas and electricity shares increase from 28.7% to 30.3% (natural gas) and from 14.9% to 15.6% (electricity). As in OECD, the fastest-growing forms of industrial sector energy consumption in the non-OECD region from 2012 to 2040 are natural gas (2.2%/year) and electricity (1.6%/year). Non-OECD consumption of renewable energy also expands rapidly, by an average of 1.7%/year from 2012 to 2040, while consumption of liquid fuels and coal increases by 1.4%/year and 0.8%/year, respectively (Figure 7-3). Most of the world growth in industrial sector energy use occurs in the emerging non-OECD economies.

The strong rates of growth in industrial sector consumption of electricity and natural gas in both the OECD and non-OECD regions are attributable to increases in the other industrials group of nonenergy-intensive manufacturing (see Table 7-1). Although the other industrials are not energy intensive, they do make up approximately 30% and 36% of total OECD and non-OECD industrial sector delivered energy consumption, respectively. Moreover, the manufacture of bulk chemicals in the non-OECD region expands rapidly in the Reference case. Because nonenergy-intensive manufacturing—including both other industrials and other chemicals—relies heavily on electricity and natural gas, consumption of both energy sources shows strong growth in the OECD and non-OECD industrial sectors, in comparison with most other energy sources.

Biomass currently provides most of the renewable energy (excluding hydroelectricity) consumed in the industrial sector and continues to do so throughout the projection, largely because of its role in providing byproduct energy to the pulp and paper industry. OECD countries typically have either flat or declining growth in the pulp and paper industry, resulting in the slower growth

**Figure 7-2. OECD industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**

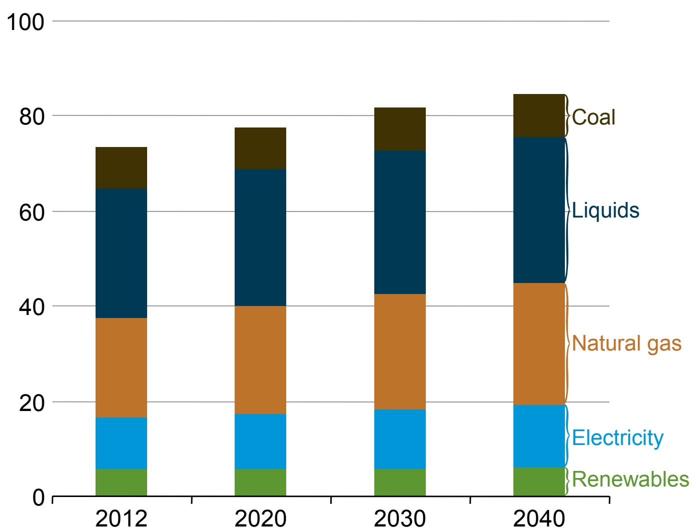
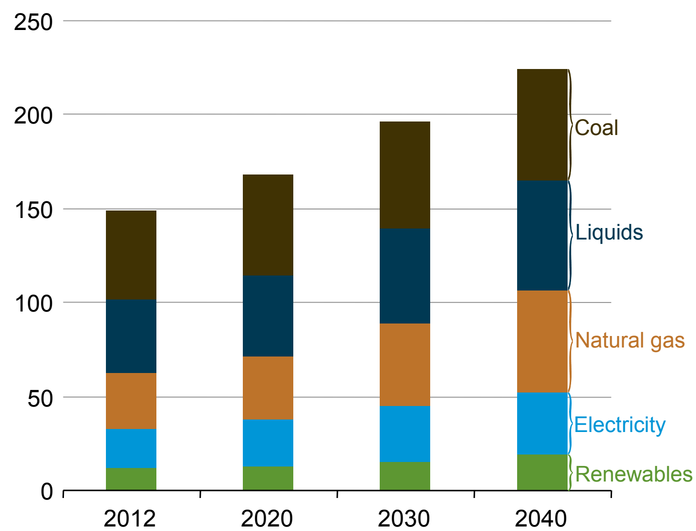



**Figure 7-3. Non-OECD industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**



of renewables compared with total industrial sector energy consumption. In most of the non-OECD countries, the pulp and paper industry grows significantly, with corresponding growth in industrial sector renewable energy use.

Coal becomes a less important source for industrial energy consumption in both the OECD and non-OECD regions in the IEO2016 Reference case. In the OECD industrial sector, coal use increases by 0.2%/year from 2012 to 2040, and its share of total delivered industrial energy consumption declines slightly, from 12% in 2012 to 11% in 2040. Similarly, in the non-OECD industrial sector, the coal share of total industrial delivered energy falls from 32% in 2012 to 27% in 2040. The iron and steel industry is the largest consumer of coal in the industrial sector, and as regions shift from coal-fired furnaces to electric arc furnaces, coal use for iron and steel production declines. In addition, several significant industrial manufacturing countries, including the United States and China, are initiating policies to reduce greenhouse gas (GHG) emissions from their industrial sectors by switching to electricity and natural gas and by improving energy efficiency in industries that produce large amounts of GHG emissions.

## Energy-intensive industries

The following industries are considered to be energy-intensive: food, pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (primarily aluminum), and nonmetallic minerals (primarily cement). Together, they account for about half of all industrial sector delivered energy use. In 2012, OECD energy-intensive industries accounted for about 54% of the region's total industrial sector energy consumption, and non-OECD energy-intensive industries accounted for about 51% of the industrial sector total. Consequently, the quantity and fuel mix of future industrial sector delivered energy consumption will be determined largely by the overall levels of energy consumption in those seven industries. In addition, the same industries emit large quantities of carbon dioxide (CO2), related to both their energy consumption (combustion emissions) and their production processes (process emissions). Figure 7-4 and Figure 7-5 show energy consumption shares of the energy-intensive industries compared with all industrial sector energy consumption (including feedstock consumption) in 2012 and 2040 for the OECD and non-OECD, respectively. The energy consumption shares of the energy-intensive industries are shown as percentages of total delivered energy consumption in the OECD and non-OECD industrial sectors.

Increases in energy efficiency and changes in industrial gross output affect the growth of industrial sector energy consumption. Anticipated energy efficiency improvements in the industrial sector temper the growth of industrial energy demand, particularly for the energy-intensive industries. Recycling is a key contributor to industrial energy efficiency improvements, especially in the pulp and paper, iron and steel, and nonferrous metals industries *(see box on page 120)*.

Among the energy-intensive industries, the largest consumer of delivered energy is the basic chemicals industry, which in 2012 accounted for about 19% of total delivered energy consumption in the OECD industrial sector and about 14% in the non-OECD industrial sector. In both regions, the basic chemicals share of industrial energy use in the IEO2016 Reference case rises to about 20% in 2040 (Figure 7-4 and Figure 7-5). The chemicals industry in general uses petrochemical feedstocks, which are included in its energy use. In 2012, petrochemical feedstocks accounted for roughly 60% of the energy consumed in the chemicals sector (which includes both energy-intensive basic chemicals and nonenergy-intensive other chemicals). Intermediate petrochemical products (or building blocks), which go into products such as plastics, require a fixed amount of hydrocarbon feedstock as input. For any given amount of chemical output, depending on the fundamental chemical process of production, a fixed amount of feedstock is required, which greatly reduces opportunities for decreasing fuel consumption in the absence of any major shifts toward recycling and bio-based chemicals.

**Figure 7-4. Energy-intensive industry shares of total OECD industrial sector energy consumption, 2012 and 2040 (percent of total)**

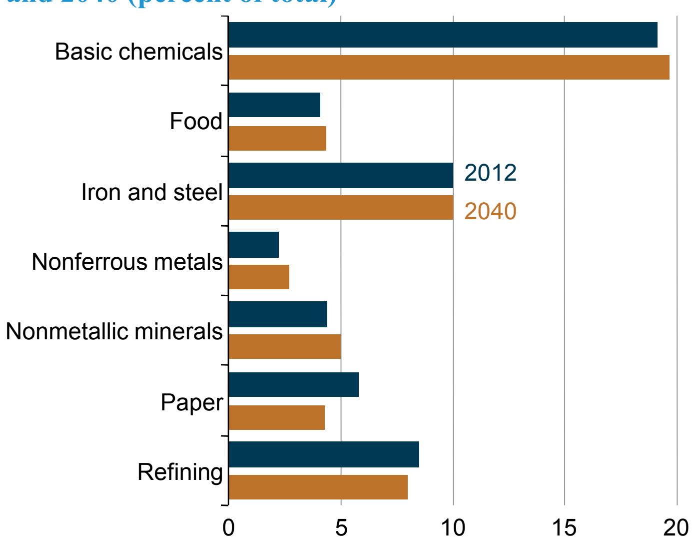
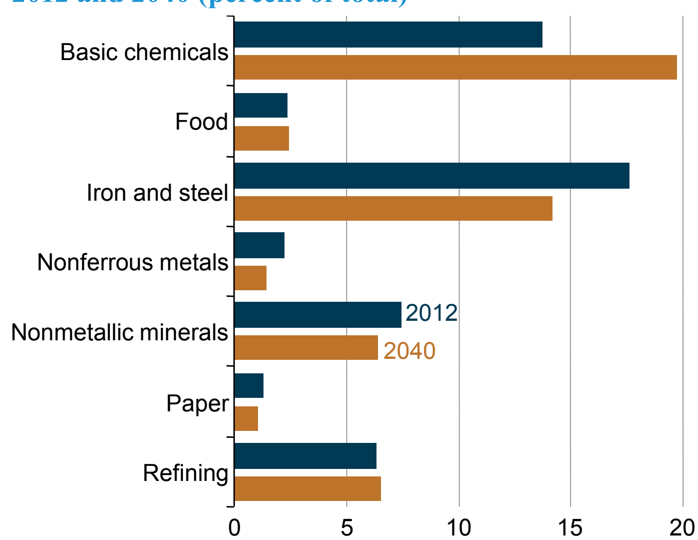



**Figure 7-5. Energy-intensive industry shares of total non-OECD industrial sector energy consumption, 2012 and 2040 (percent of total)**



The iron and steel industry accounted for about 10% of industrial sector delivered energy consumption in OECD countries in 2012, and its 2040 share remains the same in the IEO2016 Reference case. In the non-OECD countries, the iron and steel industry accounted for 18% of delivered industrial sector energy use in 2012, and its share declines to about 14% in 2040. The amount of energy consumed in the production of steel depends on the process used. In the blast furnace process, iron ore is reduced (meaning that oxygen molecules in the ore bond with the carbon molecules), leaving pure molten iron and carbon dioxide. The molten iron is transferred to a basic oxygen furnace, where super-heated oxygen is used to remove any remaining impurities. Coal consumption and heat generation make the process highly energy intensive. In addition, the process requires metallurgical coal (coking coal), which is more costly than steam coal because of its lower ash and sulfur content.[296]

The other major steel production process uses electric arc furnaces to melt scrap metal. The process is more energy efficient and produces less carbon dioxide than the blast furnace process but depends on a reliable supply of scrap steel. As a supplement to scrap steel, direct reduced iron (DRI) can be used in electric arc furnaces. DRI is much less energy-intensive than the blast furnace process, requiring only natural gas or steam coal, rather than coking coal.

The refining industry is a major energy consumer, accounting for about 8% of delivered industrial energy consumption in OECD countries and about 6% of delivered industrial energy consumption in non-OECD countries throughout the 2012–40 period. Petroleum refineries are by far the largest consumers of energy in this industry. Their energy consumption is related primarily to demand for liquid fuels (primarily in the transportation sector), with some reduction in their energy use related to increases in energy efficiency. OECD countries have a small increase in liquids demand in the projection with a small increase in refinery energy consumption. Thus, the percentage of industrial sector delivered energy consumption accounted for by refinery use falls slightly from 2012 to 2040, as a result of small increases in overall industrial sector energy consumption (about 13%) from 2012 to 2040. In contrast, demand for liquids in the non-OECD countries grows significantly. With increases in refinery energy consumption, the refinery share of total industrial sector delivered energy consumption rises slightly.

In parallel with the large growth in industrial sector energy consumption in non-OECD countries overall, energy consumption in the nonmetallic minerals industry increases significantly over the projection. In 2012, the nonmetallic minerals industry accounted for about 5% of total OECD delivered industrial energy consumption and about 7% of total non-OECD delivered industrial energy consumption. Increases in the industry's energy use result primarily from growth in the construction industry, which is accompanied by growing demand for cement.

Non-OECD countries are experiencing significant population growth, which contributes to similar growth in the food industry in the IEO2016 Reference case. In 2012, the food industry accounted for about 4% of total delivered industrial energy consumption in OECD countries and 2% in non-OECD countries. With the large growth in non-OECD industrial sector energy consumption in the Reference case, the food industry share of the sector's total energy use remains at 4% in 2040.

The pulp and paper industry accounted for about 6% of delivered industrial energy consumption in OECD countries in 2012, and its share declines to about 4% in 2040 in the IEO2016 Reference case. In the non-OECD countries, pulp and paper production accounts for about 1% of total delivered industrial energy consumption. Paper manufacturing is an energy-intensive process, but paper mills typically generate about half of the electricity they consume through cogeneration, primarily with black liquor and biomass from wood waste. In some cases, integrated paper mills generate more electricity than they need, and they are able to sell their excess power to the grid. As is the case in other industries, recycling significantly reduces the energy intensity of production in the paper industry.[297] Electronic media and digital file storage in many countries may cause global demand for paper to contract over time. For much of the rest of the world, however, output from the paper industry expands steadily in the IEO2016 Reference case, in part because of a growing need for a variety of paper products in non-OECD Asia, including paperboard for packaging and other materials. With the large increase in industrial sector energy consumption in non-OECD countries, the static percentage of the paper industry indicates a significant increase in energy consumption associated with increasing demand.

The nonferrous metals industry (primarily aluminum) accounted for about 2% of delivered industrial energy consumption in both the OECD and non-OECD regions in 2012. A small decrease in the industry's share of total non-OECD industrial energy consumption in 2040 results from the increase in total industrial sector energy use as a result of growing demand.

## Regional focus: OECD Europe and non-OECD Asia

Regions around the world have different industrial sector energy profiles and may develop in different ways in the future. The OECD Europe and non-OECD Asia regions illustrate several differences. OECD Europe is a well-established industrialized region, where the major concern is implementing government policies that will improve energy efficiency and decrease GHG emissions. In contrast, much of non-OECD Asia is still developing, and although there are efforts underway to address pollution issues in the industrial sector, there is also significant government interest in increasing industrial growth that will help the non-OECD Asian economies raise incomes and standards of living. The industrial sectors of the OECD Europe and non-OECD Asia regions illustrate the range of world industrial development and future growth in the IEO2016 Reference case.

[296] D. Paul, "Modeling the U.S. Iron and Steel Industry," U.S. Energy Information Administration Task Order DE-DT0001606, Subtask 1.2 (Leidos: November 15, 2013).

[297] D. Paul, "Final Report: Modeling the U.S. Pulp and Paper Industry," U.S. Energy Information Administration Task Order 7965, Subtask 17 (Leidos: July 15, 2015).

### *OECD Europe*

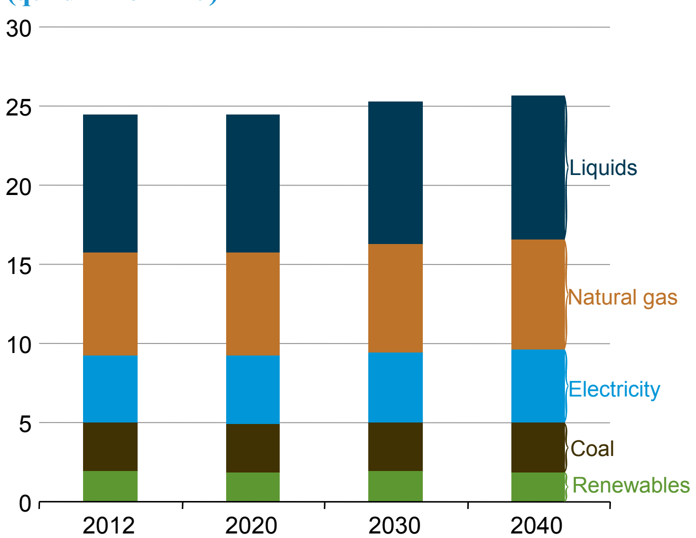
In the IEO2016 Reference case, OECD Europe's industrial sector energy consumption growth averages 0.2%/year from 2012 to 2040 (Figure 7-6), reflecting improving efficiency in the region's industrial sector and its continued transition from a manufacturing economy to a service economy. Electricity consumption has the highest rate of growth, at 0.3%/year, while the growth rates for natural gas, electricity, and liquids consumption are higher than those for other fuels. The growth rates for consumption of all fuels are positive, except for renewables with a slow decline from 1.93 quadrillion Btu in 2012 to 1.87 quadrillion Btu in 2040. The gross output of pulp and paper declines toward the end of the projection period, and improvements in energy efficiency slow the growth of renewable energy use.

Energy and environmental policies significantly influence the trends in industrial sector energy consumption in OECD Europe. European Union (EU) climate and energy policies, part of the current Europe 2020 strategy, are concerned with reducing GHG emissions. The so-called 20-20-20 plan set three separate goals to be achieved by 2020: (1) reduce GHG emissions by 20% compared with 1990; (2) increase renewable energy to 20% of final energy consumption; and (3) improve energy efficiency by 20%. To date, there has been mixed success in efforts to reach the 20-20-20 targets. From 1990 to 2012, the EU reduced GHG emissions by 18%, and it seems likely that it will achieve its 20% target for 2020. Further, 13% of EU final energy consumption in 2011 came from renewable sources—exceeding the 2011–12 interim goal of 10.7%.[298] However, only a 17% improvement in energy efficiency is expected from measures under the 2012 Energy Efficiency Directive.[299] The European Commission published the Strategy for a European Energy Union in February 2015, with a focus on energy security, completion of an internal energy market, energy efficiency, decarbonization, and research and innovation. Implementation of the strategy will require new EU legislation.[300] Because of these efforts, slow growth in energy use in industry is expected.

## Non-OECD Asia

Over the past decade, much of the world's industrial sector energy growth occurred in the nations of non-OECD Asia. That trend continues in the IEO2016 Reference case with strong expansion of the region's manufacturing and nonmanufacturing industries. From 2012 to 2040, non-OECD Asia's expected total industrial sector delivered energy consumption increases by an average of 1.7%/year, as compared with the world average of 1.2%/year.

**Figure 7-6. OECD Europe industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**




### *China*

#### *Steel energy demand growth in China*

Steel is a major energy-intensive industry in China, and the amount of steel being produced in China is unprecedented. China's share of world steel production has increased steadily from roughly one-quarter in 2004 to about one-half in 2013.[301] Primary steel (virgin steel from iron ore)—or, more specifically, basic oxygen furnace (BOF) steel[302]—is a major consumer of coal in China and therefore a major contributor to industrial sector GHG emissions.

Steel production in China continues to grow throughout the projection period but not as rapidly as during the past decade. From 2005 to 2012, gross output in China's iron and steel industry grew at an average annual rate of 12% (and crude steel production closely matched that growth rate at 11%). From 2012 to 2040 in the IEO2016 Reference case, the average growth rate is only 3%. Even at that rate, however, gross output shipments from the industry more than double from 2012 to 2040, while the industry's energy consumption increases by only 11% over the period. The disparity between shipments and energy consumption growth results from the

[298]European Commission, "Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Renewable Energy Progress Report" (Brussels: March 27, 2013), p. 3, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0175&from=EN.

[299]European Parliamentary Research Service, "EU climate and energy policies post-2020: Energy security, competitiveness and decarbonisation" (Briefing 24/03/2014), http://www.europarl.europa.eu/RegData/bibliotheque/briefing/2014/130681/LDM_BRI(2014)130681_REV1_EN.pdf.

[300]European Parliament, "Energy Union: New impetus for coordination and integration of energy policies in the EU" (Briefing 5 March 2015: Tracking European Commission priority initiatives in 2015 – Number 1), http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551310/EPRS_BRI(2015)551310_EN.pdf.

[301]World Steel Association, *Steel Statistical Yearbook 2014* (Brussels, Belgium: worldsteel Committee on Economic Studies, October 2014), http://www.worldsteel.org/dms/internetDocumentList/statistics-archive/yearbook-archive/Steel-Statistical-Yearbook-2014/document/Steel-Statistical-Yearbook-2014.pdf.

[302]"Blast furnace steel" refers to the process of reducing iron ore in a blast furnace and processing the molten steel in a basic oxygen furnace.

Reference case assumption of energy efficiency improvements in technologies (hot and cold rolling, electric arc furnaces, blast furnaces) over time, as well as an assumed shift from BOF steel production to electric arc furnace (EAF) production, with the energy intensity of the EAF process less than one-third of that for the BOF process.[303] In aggregate, the total energy intensity of China's iron and steel industries (in units of energy per dollar value of gross output shipments) declines by 69% from 2012 to 2040.

One reason for the decline in energy intensity is the assumption that China, like most developed nations, will rely increasingly on recycled—as opposed to virgin—BOF steel. In 2013, the BOF and EAF process shares in China for crude steel production were 91% and 9%, respectively. Most of the world's major steel-producing nations currently produce far more recycled steel as a share of their total production than does China. In Japan and the United States, which are the second- and third-largest producers in the world, the EAF shares are 23% and 59%, respectively. Thus, currently, the energy intensity of China's steel industry seems very high compared with other major producers, in large measure because of its heavy reliance on BOF steel. As China's economy becomes more developed and moves toward recycling of scrap steel, its energy intensity will decrease. The gradual move toward recycling (spurred by the increasing availability of scrap steel) is expected as expansion of new buildings construction, infrastructure, and vehicle fleets begins to taper off. In the IEO2016 Reference case, the EAF share of steel production grows to 40% in 2040, which is in line with other projections for China's recycled steel production.[304]

## Steel and aluminum recycling in China

Secondary production from recycled scrap metal, which uses significantly less energy than primary production from raw material inputs, can reduce the energy intensity of both steel and aluminum production.[305] The Institute of Scrap Recycling Industries estimates that recycling steel requires 60% less energy than producing steel from iron ore. According to the U.S. Department of Energy, secondary aluminum production requires as little as 6% of the energy associated with primary production, when all manufacturing energy use is considered.[306] Recyclable material includes both post-consumer scrap and pre-consumer scrap from manufacturing processes.

In China, which produces more steel and aluminum than any other country, the iron and steel industry used 16 quadrillion Btu of energy in 2012, and the nonferrous metals industry (which includes aluminum and other metals) used 2.1 quadrillion Btu.[307] In comparison with the United States, China's aluminum and steel recycling rates are low. In 2012, about 11% of China's crude steel production was secondary production (from recycling),[308] and 21% of its aluminum production was secondary production.[309] In contrast, U.S. recycling rates were 59% for steel production and 57% for aluminum production.

The two main barriers to increasing the use of scrap in secondary production of steel and aluminum are capital investment and availability of scrap. Although increasing secondary production does require additional secondary production facilities, costs for those facilities are much lower than the costs of primary production facilities. For example, the capital equipment costs for recycled aluminum production are approximately 10% of those for primary aluminum production.[310]

Steel and aluminum scrap sources include obsolete buildings and transportation equipment, as well as discarded appliances and beverage cans. Domestic scrap is usually less expensive than imported scrap, but it requires dedicated sorting, collection, and transportation, as well as access to large volumes of scrap material. Based on an analysis of China's steel industry structure in 2011,[311] recycling of scrap metal could be increased to 33% of total steel production without adding new secondary processing facilities.

*(continued on page 121)*

[303] E. Worrell, P. Blinde, M. Neelis, E. Blomen, and E. Masanet, *Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel industry: An ENERGY STAR® Guide for Energy and Plant Managers,* LBNL-4779E (Berkeley, CA: Lawrence Berkeley National Laboratory, Environmental Technologies Division, October 2010), https://www.energystar.gov/ia/business/industry/Iron_Steel_Guide.pdf.

[304] A. Hasanbeigi, Zeyi Jiang, and L. Price, "Why the energy use of Chinese steel industry may peak as early as 2015?" (Berkeley, CA: Lawrence Berkeley National Laboratory, 2014), http://proceedings.eceee.org/visabstrakt.php?event=4&doc=3-008-14.

[305] U.S. Energy Information Administration, "Recycling is the primary energy efficiency technology for aluminum and steel manufacturing" (Washington, DC: May 9, 2014), http://www.eia.gov/todayinenergy/detail.cfm?id=16211.

[306] Institute of Scrap Recycling Industries, Inc., *Recycling Industry* (undated), http://www.isri.org/recycling-industry; and U.S. Department of Energy, Energy Efficiency and Renewable Energy, *U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and Current Practices* (Washington, DC: February 2007), http://www1.eere.energy.gov/manufacturing/resources/aluminum/pdfs/al_theoretical.pdf.

[307] U.S. Energy Information Administration, "Recycling is the primary energy efficiency technology for aluminum and steel manufacturing" (Washington, DC: May 9, 2014), http://www.eia.gov/todayinenergy/detail.cfm?id=16211.

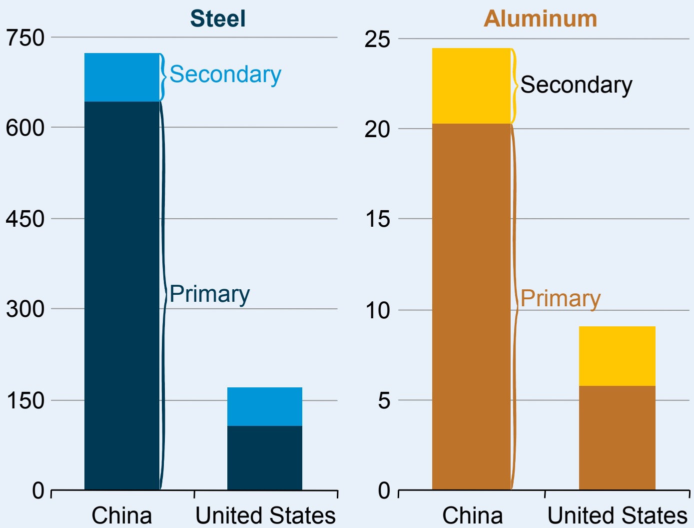
[308] Bureau of International Recycling, Ferrous Division, *World Steel Recycling in Figures 2008-2012,* http://www.bdsv.org/downloads/weltstatistik_2008_2012.pdf.

[309] United States Geological Survey, *Mineral Industry of China Data for 2012,* http://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-ch.xls; and United States Geological Survey, *Minerals Information, Recycling Statistics and Information,* http://minerals.usgs.gov/minerals/pubs/commodity/recycle/.

[310] U.S. Department of Energy, Energy Efficiency and Renewable Energy, *U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and Current Practices* (Washington, DC: February 2007), http://www1.eere.energy.gov/manufacturing/resources/aluminum/pdfs/al_theoretical.pdf.

[311] J. Wubbeke and T. Heroth, "Challenges and political solutions for steel recycling in China," *Resources, Conservation and Recycling,* Vol. 87 (June 2014), pp. 1-7, http://www.sciencedirect.com/science/article/pii/S0921344914000627.

**Figure 7-7. Steel and aluminum production from primary and secondary sources in China and the United States, 2012 (million metric tons)**



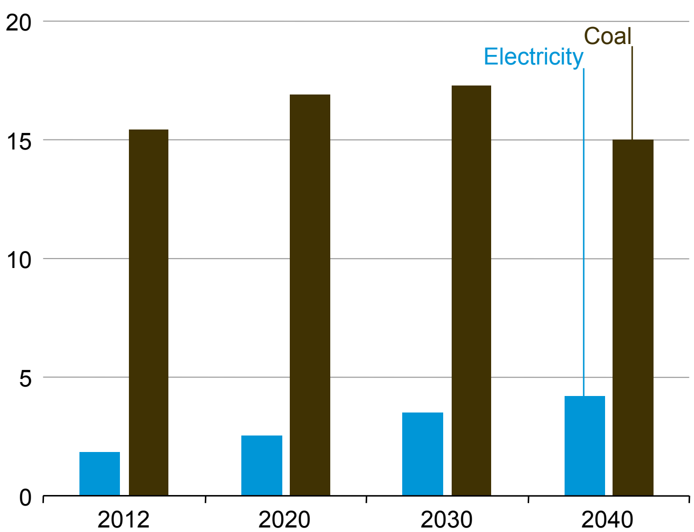

In 2012, China imported almost 5 million metric tons of steel scrap and 2.6 million metric tons of aluminum scrap[312] (Figure 7-7). Because the iron and steel industry is a much larger energy consumer than the aluminum industry, China's government aims to increase scrap input by improving recycling efficiency in the iron and steel industry. Over time, more scrap could become available in China, allowing a substantial reduction in the energy intensity of the country's steel and aluminum industries.

With the relative increase in EAF production, the electricity demand share in the steel industry rises from 10% in 2012 to 22% in 2040 (Figure 7-8). Concurrently, total energy intensity decreases by 69% due to the much lower energy intensity of the EAF process as well as ongoing energy intensity improvement, which in part follow from necessary reductions in excess steel capacity.[313] Although much of the electricity used for EAF production is expected to be generated by coal-fired power plants, the reduction in blast furnace production of steel greatly reduces the steel industry's dependence on coal (per ton of steel produced) and thus contributes to lower energy intensity and lower GHG intensity.

### *Chemicals industry growth and coal consumption*

As with other energy-intensive industries, China's chemicals industries have experienced rapid growth. In terms of gross output shipments, bulk chemicals (which include petrochemical and commodity chemicals) grew by almost 70% from 2005 to 2012 (an average rate of 7.8%/year), while in terms of physical production, chemicals such as ethylene, propylene, and methanol had even stronger growth. China's robust growth in bulk chemicals production is projected to continue in the Reference case—in line with the growth in virtually all other industrial categories—with gross output increasing by an average of 5.0%/year.

**Figure 7-8. Coal and electricity consumption in China's steel industry, 2012–40 (quadrillion Btu)**




Changes in China's economy support the projected growth of its bulk chemicals industry. Olefins, including ethylene and propylene, are inputs for a wide variety of industrial and consumer chemicals, such as resins, plastics, and adhesives. Reducing dependence on imports of commodity chemicals while still satisfying industrial production growth is a major factor in China's continued expansion of its chemical industry. Methanol is another input for China's growing market for chemical derivatives, as is propylene; however, methanol also satisfies growing demand for liquid fuels in China's transportation sector.[314] Currently, China produces about one-third of the world's ammonia,[315] and although China is

[312]United States Geological Survey, *Mineral Industry of China Data for 2012*, http://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-ch.xls.

[313]Chuin-Wei Yap, "The Fall of Steel in China: a Primer" (*The Wall Street Journal*, September 8, 2015), http://blogs.wsj.com/chinarealtime/2015/09/08/the-fall-of-steel-in-china-a-primer/.

[314]G. Dolan, "Will Politics Push the Gas or Brakes on Methanol Fuel" (Methanol Institute, 2013), http://www.methanolfuels.org/wp-content/uploads/2013/05/15-Dolan_MI.pdf.

[315]L.E. Apodaca, "2013 Minerals Yearbook: Nitrogen [Advance Release]" (Washington, DC: 2013), http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/myb1-2013-nitro.pdf.

trying to reduce its level of fertilizer use,[316] its pursuit of food security and continued modernization of farming probably will result in moderate growth of fertilizer consumption in the future.

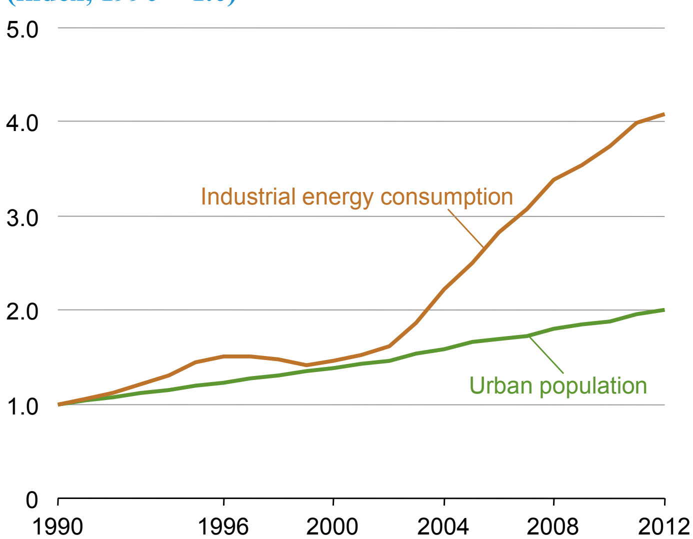
China's use of energy resources in bulk chemical production differs from use in most other large producing regions, in that it relies heavily on coal as a feedstock. Outside China, most methanol and ammonia production relies on natural gas feedstock, while ethylene production and propylene production rely largely on natural gas liquids (NGL) or on petroleum-based feedstocks. However, China continues to rely heavily (although not exclusively) on coal gasification technologies to produce many of its bulk chemicals. Currently, 70% of ammonia production[317] and more than 80% of methanol production[318] in China use coal as a feedstock, with a growing share going into the production of olefins, such as propylene and ethylene. According to its most recent Five-Year Plan, China intends to increase coal use in producing olefins.

Generally, the relative levels of use of different feedstocks depend on the delivered costs of the fuels, although other factors also matter. Coal is relatively inexpensive in China, but construction of coal-to-olefin (CTO) processing plants is not. Coal feedstock costs represent only about 25% of the total costs for CTO production because of the high capital cost of production. In contrast, for petroleum-based production of olefins, such as in a naphtha-based steam cracker, the feedstock costs for naphtha are a much higher percentage of the total production cost.[319] Thus, lower petroleum product prices will make steam crackers increasingly attractive, while lower coal prices would not have as much of an effect. In addition, the CTO process results in fewer valuable coproducts (such as butadiene and aromatics). Finally, there is a cost associated with transporting the basic olefins to China's East Coast, where most of the plastic manufacturers are located.

Environmental concerns such as CO2 emissions, water use, and waste disposal may have a larger effect on potential CTO projects. The CTO process generates more than twice as much CO2 per ton of olefin produced as a naphtha steam cracker does. The CTO process is also far more water-intensive, and most CTO projects are or will be located in water-stressed regions (such as Inner Mongolia and Western China), where water resources are well below the world average.[320] Finally, the hazardous material and waste disposal associated with CTO processes also can lead to escalating expenses for industrial-scale CTO plants.

In the IEO2016 Reference case, the coal share of China's chemical feedstock fuel use is projected to increase from 20% to 32% from 2012 to 2040, while the liquids share (mostly heavy petroleum feedstocks) declines by 6%. The difference results from the higher proportion of new ethylene crackers using coal instead of naphtha and gasoil for feedstock. The natural gas share of feedstock fuel use also increases, with some of China's projected growth in ammonia and methanol production capacity using natural gas and not exclusively coal.

**Figure 7-9. Industrial energy consumption and urban population growth in China, 1990–2012 (index, 1990 = 1.0)**




## Urbanization and industrial energy demand in China

From 1990 to 2012, China's industrial energy consumption increased fourfold, from 14.8 quadrillion Btu to 59.0 quadrillion Btu. A review of the literature on the Chinese experience indicates that the 10th Five-Year Plan (2001–05) promoted strong growth in the manufacturing sector, resulting in 13.5% annual average growth in GDP for that period. The focus on the use of advanced technology across traditional manufacturing enterprises[321] contributed to a rapid increase in production across a wide range of industries and a corresponding increase in industrial energy consumption (Figure 7-9), with industrial sector energy use rising by 3.9%/year from 1990 and 2000, followed by 9.8%/year from 2001 to 2012.

The energy intensity of China's gross domestic product (GDP), or energy use per dollar of GDP, has generally improved (decreased) since 1990 from a level more than three times higher than in the OECD countries to a level two

[316] L. Jin, "China's 12th 5-Year Plan: Sustainability" (KPMG Advisory China, Ltd: April 2011), https://www.kpmg.com/CN/en/IssuesAndInsights/ArticlesPublications/Documents/China-12th-Five-Year-Plan-Sustainability-201104-v2.pdf.

[317] J. R. Bartels, "A Feasibility Study of Implementing an Ammonia Economy" (Iowa State University, 2008), http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=2119&context=etd.

[318] C. Yang, "Coal Chemicals: China's High-Carbon Clean Coal Programme?" (Taylor and Francis Group: 2016), http://people.duke.edu/~cy42/C2C.pdf.

[319] D. Hurd, S. Park, and J. Kan, *China's Coal to Olefins Industry* (Deutsche Bank AG, Hong Kong: July 2, 2014), http://www.fullertreacymoney.com/system/data/files/PDFs/2014/July/3rd/0900b8c088667819.pdf.

[320] S. Moore, "Issue Brief: Water Resources Issues, Policy and Politics in China" (Washington, DC: February 12, 2013), http://www.brookings.edu/research/papers/2013/02/water-politics-china-moore.

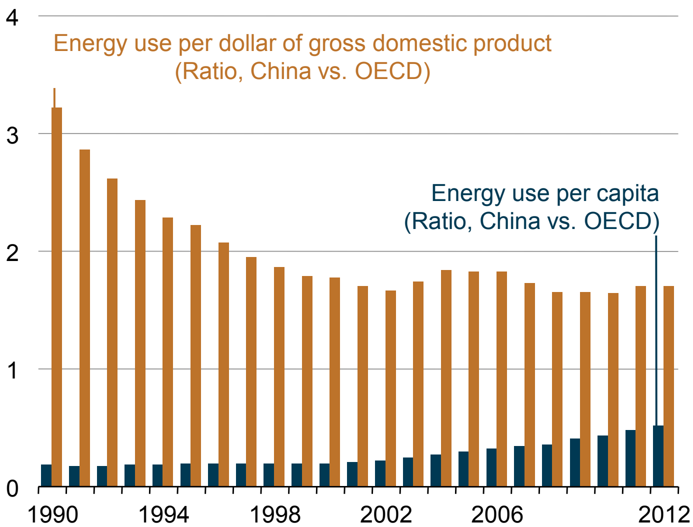
[321] Z. Ronghji, "Report on the Outline of the Tenth Five Year Plan for National Economic and Social Development (2001)," http://www.gov.cn/english/official/2005-07/29/content_18334.htm.

times higher in the mid-1990s. That progress was interrupted from 2000 to 2005, however, when aggressive manufacturing goals set in China's 10th Five-Year Plan led to increases in energy intensity as production rose across many industries. During that period, energy intensity increased to 1.8 in 2004, before settling at levels that were between 1.6 and 1.7 times the OECD level through 2012 (Figure 7-10).

Under the terms of the 12th Five-Year Plan (2011–15), China for the first time implemented specific targets aimed at reducing energy intensity (a 16% reduction in energy use per dollar of GDP, which would reduce intensity to 40% above OECD levels by 2015). Many observers expect that the 13th Five-Year Plan (2016–20) will continue to target additional energy efficiency gains,[322] along with a variety of other measures designed to reduce emissions.

Figure 7-11 shows the increase in China's energy consumption for both fuel and feedstock in the chemical industry. Feedstock plays a prominent role in the production of bulk chemicals, and there is little efficiency improvement to be gained for a given feedstock type (as opposed to heat and power uses, where incremental efficiency gains in boilers, power generation, motors, etc., have occurred in the past and are expected in the future). Consequently, the overall energy efficiency improvement in this industry from 2012 to 2040 is not expected to be significant, with overall intensity improvement at only 15%.

**Figure 7-10. Comparisons of energy use per capita and per dollar of gross domestic product in China and the OECD, 1990–2012 (1990 OECD = 1)**




## Other non-OECD Asia

The nations of non-OECD Asia outside China and India (or other non-OECD Asia) are some of the fastest-growing industrial energy-consuming nations worldwide. Total industrial energy use in other non-OECD Asia increases from 15.7 quadrillion Btu in 2012 to 26.6 quadrillion Btu in 2040, according to the IEO2016 Reference case, an average annual increase of 1.9% (Figure 7-12). Other non-OECD Asia's industrial sector energy consumption grows at a rate higher than the combined OECD rate (0.5%/year), as well as the rate for the combined total non-OECD (1.5%/year). In general, the nations of other non-OECD Asia have among the highest projected growth in industrial sector gross output and associated delivered energy consumption. However, the focus on energy efficiency and the product mix also affects the delivered energy consumption growth rate. The fuels whose consumption grows most quickly in other non-OECD Asia are natural gas (2.2%/year between 2012 and 2040) and electricity (2.0%/year), although liquid fuels (1.8%/year), coal (1.8%/year), and renewables (1.8%/year) also grow rapidly. The fuel shares change very little over the projection period.

**Figure 7-11. Fuel and feedstock consumption in China's bulk chemicals industry, 2012–40 (quadrillion Btu)**

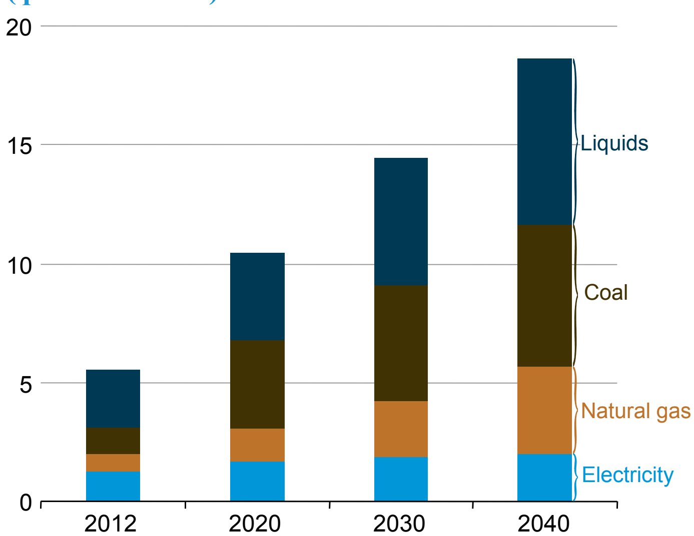
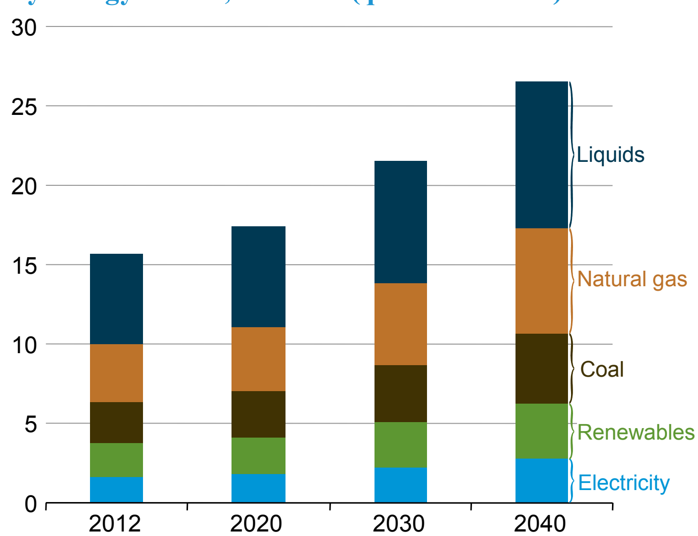



**Figure 7-12. Non-OECD Asia (excluding China and India) industrial sector delivered energy consumption by energy source, 2012–40 (quadrillion Btu)**




[322]For example, see Energy & Climate Intelligence Unit and China Dialogue, "China Heads to Low Carbon Future" (Davos, Switzerland: 2014), http://eciu.net/assets/ECIU_China-Doc-151015-FINAL.pdf.

The countries that are members of the Association of South East Asian Nations (ASEAN)[323] have the highest growth rates among the other non-OECD Asia countries. Energy efficiency is viewed as one of the most cost-effective ways of enhancing energy security and addressing climate change, as well as promoting economic competitiveness, in the ASEAN member countries. ASEAN is concerned with both energy efficiency and climate change, with the following strategic objectives[324]:

- To pursue the aspirational goal of reducing regional energy intensity by at least 8% in 2015 from the 2005 level
- To achieve higher end-use energy efficiency for all sectors through regulatory and market approaches, where appropriate
- To enhance institutional and human capacity, emphasizing the development of energy efficiency technology and service providers in the ASEAN region
- To encourage private sector participation, especially by financial institutions, in support of energy efficiency and conservation investment and implementation.

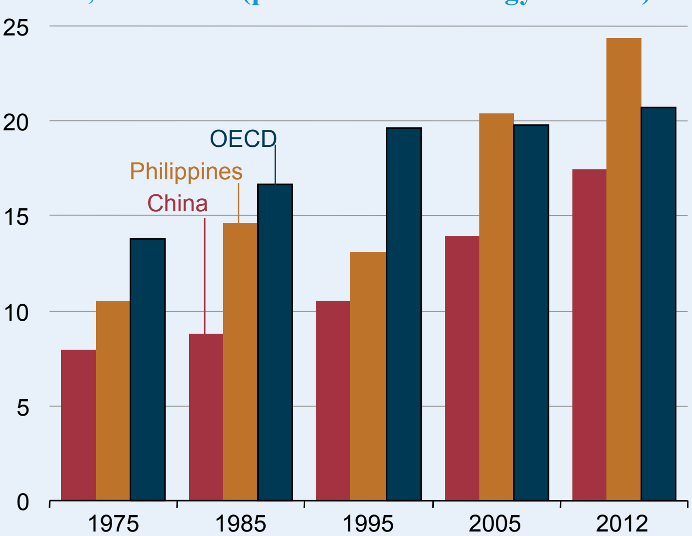
## Role of electricity in changing patterns of non-OECD Asia industrial energy use

Since the 1970s, industrial sector energy demand has varied significantly among the non-OECD nations of Asia. In 2012, the electricity share of industrial energy demand ranged from 11% in Northeast Asia (Mongolia and North Korea) to nearly 25% in the Philippines (Figure 7-13). The way industrial sectors in the non-OECD Asia nations have developed over time can provide a basis for understanding the variables that may influence industrial sector electrification in the future.

In the industrialized OECD nations, electricity penetration in the industrial sector has been linked with fuel substitution in production processes (for example, replacing inefficient blast furnaces with electric arc furnaces) and the development of new uses for electricity in increasingly mechanized industries.[325] In rapidly growing Asian markets, however, industry is expanding through investment in new industrial facilities that incorporate the latest and most energy-efficient technologies.

China has experienced significant growth in industrial sector electricity demand—averaging approximately 9%/year and outpacing demand growth for all other fuels used in industrial production. The electricity share of industrial energy use in other non-OECD Asia nations also has increased rapidly. Since the early 1970s, industrial electricity use has doubled every eight years in China and in member countries of the Association of Southeast Asian Nations (ASEAN). As economic reform was unfolding in China, industrial electricity demand surged from 984 terawatthours (TWh) in 2000 to 1,802 TWh in 2005. By the end of the decade, China had recorded double-digit annual growth in total electricity demand, with a commensurate rise in the electricity share of industrial energy consumption, to 18% in 2012—close to the overall share in the OECD countries. Over the same period, industrial electricity demand in the ASEAN countries increased from 182 TWh in 2000 to 399 TWh in 2012, when it accounted for 12% of total industrial energy use.

**Figure 7-13. Electricity shares of industrial sector energy demand in China, the Philippines and the OECD, 1975–2012 (percent of total energy demand)**




A disaggregated view of electricity demand growth in China's industrial sector reflects the structural changes occurring as the economy grew (Figure 7-14). In the 1990s and early 2000s, the electricity share of industrial energy demand in China's energy-intensive industries (including iron and steel, pulp and paper, chemicals, and food) rose modestly, to 13%. Since 2000, nonenergy-intensive industries (including transport and electrical equipment and computers) have accounted for an increasing share of industrial electricity demand. For 2012, the electricity share of industrial energy demand was 18%.

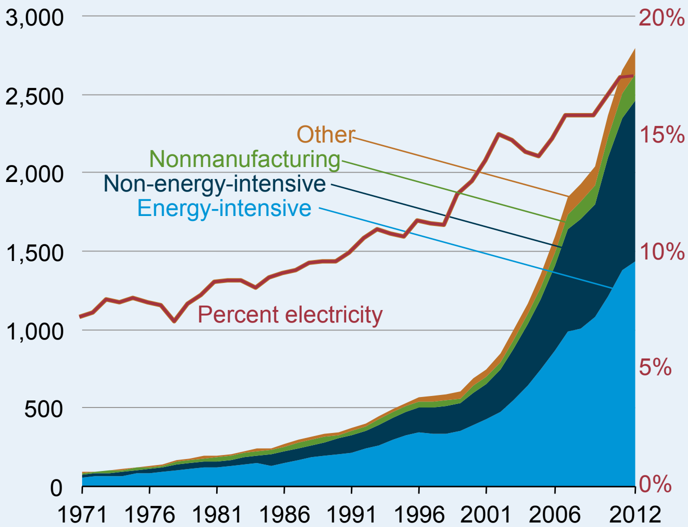
In comparison with China, the Philippines shows a more variable historical trend of electricity use in the industrial sector (Figure 7-15). The electricity share of industrial sector energy demand in the Philippines moved between 15% and 20% in the late 1990s before increasing to 24% in 2012, when it exceeded the OECD level. Most of the growth in the country's industrial sector electricity demand occurred in energy-intensive industries. Unlike China, industrial demand for electricity in the Philippines is not distributed across a wide range of sectors and corresponds more closely to changes in gross output or to changes in total value added.

*(continued on page 125)*

[323]ASEAN member countries include Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.
[324]ASEAN Centre for Energy, "Energy Efficiency and Conservation" (Jakarta, Indonesia: 2015), http://www.aseanenergy.org/programme-area/eec/.
[325]N. Desbrosses, "Understanding electrification of industrial energy consumption in Europe," *Leonardo ENERGY* (February 2012), http://www.leonardo-energy.org/blog/understanding-electrification-industrial-energy-consumption-europe.

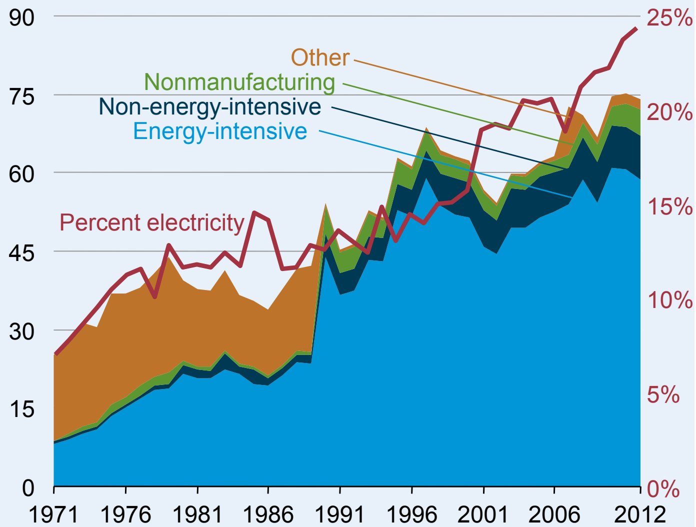
The future rate of electric demand growth in non-OECD Asia industries is more dependent on the changing composition of industry than on overall economic growth. Growth in new electricity-intensive technologies occurs largely in downstream industries—notably, nonenergy-intensive lighter manufacturing. In addition, when advanced economies reach a certain stage in their development, the growth of industrial sector electricity demand slows. As indicated by recent data, the electricity share of total industrial energy consumption in the United States and in other OECD countries has been relatively unchanged since 1990. In the United States, electricity accounted for 15% of total delivered industrial energy consumption in 2012 and is projected in the IEO2016 Reference case to account for 16% of total delivered industrial energy consumption in 2040.

**Figure 7-14. Industrial sector electricity demand in China by industry type, 1971–2012 (terawatthours)**




Note: *Other* industries category represents all nonspecified industrial sector electricity consumption as reported to the International Energy Agency.

**Figure 7-15. Industrial sector electricity demand in the Philippines by industry type, 1971–2012 (terawatthours)**




Note: *Other* industries category represents all nonspecified industrial sector electricity consumption as reported to the International Energy Agency.

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## Chapter 8

# Transportation sector energy consumption

## Overview

In the *International Energy Outlook 2016* (IEO2016) Reference case, transportation sector delivered energy consumption increases at an annual average rate of 1.4%, from 104 quadrillion British thermal units (Btu) in 2012 to 155 quadrillion Btu in 2040. Transportation energy demand growth occurs almost entirely in regions outside of the Organization for Economic Cooperation and Development (non-OECD), with transportation demand roughly flat in OECD regions—largely reflecting different expectations for economic growth in developing regions compared with developed regions.

In 2012, OECD nations accounted for 55% of the world's total transportation energy consumption, and the non-OECD nations accounted for 45% (Figure 8-1). In 2020, the OECD and non-OECD shares of world transportation energy use are projected to be equal. Non-OECD demand for transportation fuels continues to outpace OECD demand, and in 2040 the non-OECD regions are expected to account for 61% of global transportation energy consumption. In the non-OECD regions, where 80% of the world's population resides, transportation energy demand nearly doubles, from 47 quadrillion Btu in 2012 to 94 quadrillion Btu in 2040, with an average annual increase of 2.5%. In several of the non-OECD regions, energy consumption in light duty vehicles accounts for the bulk of the increase in total transportation energy consumption, as economic growth raises standards of living and, in turn, the demand for personal transportation.

## Transportation sector energy consumption by fuel

Worldwide, petroleum and other liquid fuels[326] are the dominant source of transportation energy, although their share of total transportation energy declines over the IEO2016 projection period, from 96% in 2012 to 88% in 2040. World transportation sector liquid fuels consumption grows by 36 quadrillion Btu in the Reference case projection, with diesel (including biodiesel) showing the largest gain (13 quadrillion Btu), jet fuel consumption increasing by 10 quadrillion Btu, and motor gasoline (including ethanol blends) increasing by 9 quadrillion Btu (Figure 8-2). Motor gasoline remains the largest transportation fuel, but its share of total transportation energy consumption declines from 39% in 2012 to 33% in 2040. From 2012 to 2040 the total transportation market share of diesel fuel (including biodiesel), which is the second-largest transportation fuel, declines from 36% to 33% and the jet fuel share increases from 12% to 14% in 2040.

The share of natural gas as a transportation fuel grows from 3% in 2012 to 11% in 2040. In 2012, pipelines accounted for 66% of transportation sector natural gas use, light-duty vehicles 28%, and buses 4%. As a result of favorable fuel economics, an increasing share of natural gas is used for transportation modes of travel other than pipelines. A strong increase is projected for the natural gas share of total energy use by large trucks in the Reference case, from 1% in 2012 to 15% in 2040. In addition, 50% of bus energy consumption is projected to be natural gas in 2040, as well as 17% of freight rail, 7% of light-duty vehicles, and 6% of domestic marine vessels.

Electricity remains a minor fuel for the world's transportation energy use, although its importance in passenger rail transportation remains high: in 2040, electricity will account for 40% of total passenger rail energy consumption. The electricity share of total

**Figure 8-1. Delivered transportation energy consumption by country grouping, 2012–40 (quadrillion Btu)**

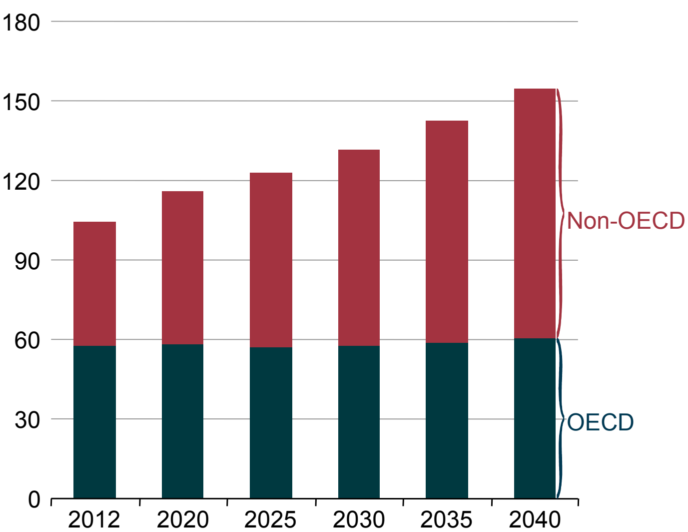
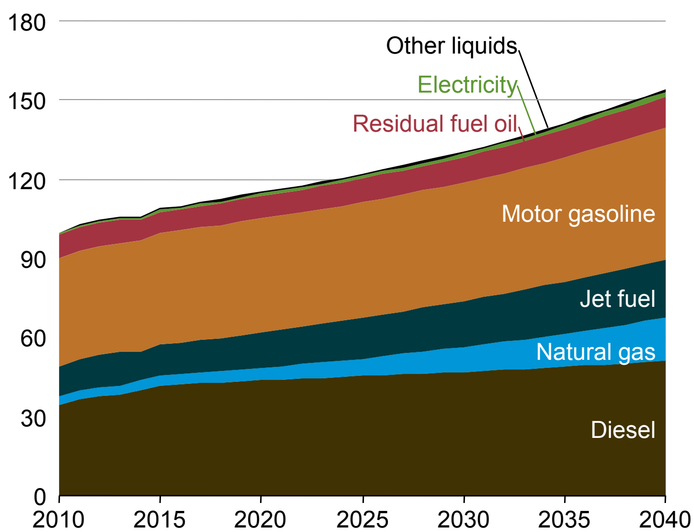



**Figure 8-2. World transportation sector delivered energy consumption by energy source, 2010–40 (quadrillion Btu)**




[326]Other liquid fuels include natural gas plant liquids, biofuels, gas-to-liquids, and coal-to-liquids.

light-duty vehicle energy consumption grows to 1% in 2040 in the Reference case, as increasing sales of new plug-in electric vehicles penetrate the total light-duty stock.

## OECD transportation sector energy consumption

The OECD as a whole does not contribute to the worldwide growth in transportation fuels consumption in the IEO2016 Reference case. OECD transportation energy consumption patterns are already well established with slow economic and population growth rates and vehicle efficiency improvements, transportation energy use for the region as a whole does not increase over the 2012–40 projection period *(see "Motor vehicle fuel economy and emissions standards by country," below).* Almost no increase in transportation energy consumption is projected for the nations in the OECD Americas, as continued fuel economy improvements offset growth in vehicle miles traveled. In Japan, an aging and declining population results in lower transportation energy use, dropping by an average of 0.7%/year, with Japan's transportation energy consumption falling from 3.9 quadrillion Btu in 2012 to 3.3 quadrillion Btu in 2040. Most of the decline in Japan's transportation fuel use is for light-duty vehicles, with smaller decreases projected for freight trucks. The largest growth in OECD transportation energy use is projected for the Mexico/Chile region. In combination, delivered transportation energy use increases by 1.2%/year from 2012 to 2040 (Figure 8-3) compared to 0.2%/year for the OECD as a whole.

## Motor vehicle fuel economy and emissions standards by country

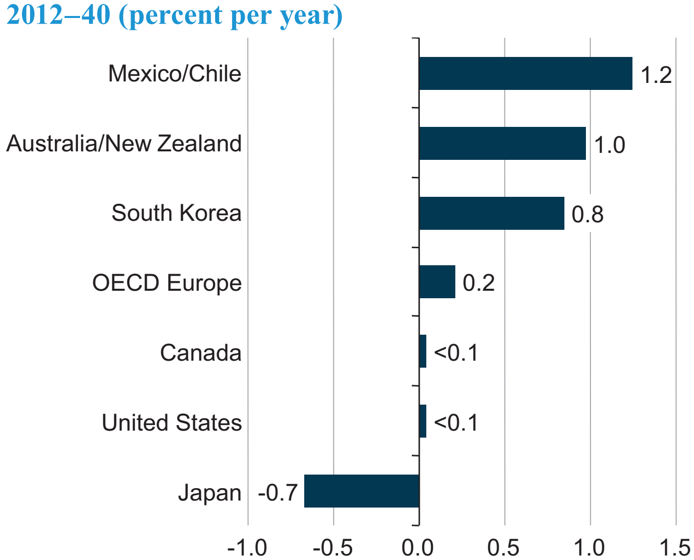
Nine countries and regions, which together account for 75% of global fuel consumption by light-duty vehicles, have adopted mandatory or voluntary standards for increasing fuel economy and reducing greenhouse gas (GHG) emissions. The intent and structure of the policies vary widely around the world. Because fuel economy and GHG emissions policies have large effects on fuel consumption, vehicle standards are among the most important components of future demand for liquid fuels.

One area of difference is the metric specified in the standard. Some standards focus on reducing GHG or carbon dioxide (CO2) emissions, some focus on improving fuel economy (or reducing fuel consumption), and others focus on combinations of the two objectives. The European Union (EU) and India have standards that specifically aim to reduce CO2 emissions. Canada's standard includes restrictions on all GHG emissions. Brazil and Japan have standards that aim to increase fuel economy, requiring light-duty vehicles to achieve specific miles-per-gallon ratings. China's standard requires light-duty vehicles to reduce fuel consumption per mile traveled. The United States and Mexico have both fuel economy and GHG standards, and manufacturers must satisfy both. South Korea's light-duty vehicle manufacturers can choose to meet either a fuel economy or a GHG emissions standard. In practice, however, the different metrics are related: improvements in fuel economy reduce CO2 emissions, and CO2 emissions are a subset of GHG emissions.

In addition, there are structural differences among the various vehicle standards. The United States, Canada, and Mexico have footprint-based corporate average fuel economy (CAFE) standards, which set GHG emissions targets (in Canada) or GHG emissions and fuel economy targets (in the United States and Mexico) based on vehicle footprint, calculated as wheelbase multiplied by average track width. The overall target for a specific manufacturer is determined by averaging the targets for the footprints of all the vehicles the manufacturer produces. Brazil, the EU, India, and South Korea have weight-based corporate average standards, which are similar to footprint-based standards but based on vehicle weight. China has a combination standard based on both vehicle weight class and corporate average fuel economy, which is more stringent than the weight-based corporate average standard alone; light-duty vehicle manufacturers in China must meet fuel consumption standards for each weight class, as well as an overall corporate average fuel consumption standard. Japan has a corporate average standard based on weight class, which requires each light-duty vehicle to meet the standard for its weight class rather than an overall standard for the manufacturer.

Fuel economy and emissions standards typically are applied to the vehicles that a company sells in a given country, rather than to all the vehicles it produces in a given country. For instance, U.S.-manufactured vehicles sold in Europe are required to meet European standards, and those sold in Japan are required to meet Japanese standards. As more countries adopt light-duty vehicle standards, differences among them are likely to persist because of variations in policy goals and consumer preferences across countries. Still, given the global nature of light-duty vehicle manufacturing, fuel economy is likely to increase for all new vehicles, and GHG emissions per mile traveled are likely to decrease.

**Figure 8-3. Annual average growth in delivered transportation energy consumption by OECD region, 2012–40 (percent per year)**



## Non-OECD transportation sector energy consumption

Virtually all (94%) of the projected growth in world transportation energy use occurs in the developing non-OECD economies, where strong economic growth leads to rising standards of living that translate to demand for personal travel and freight transport to meet growing consumer demand for goods in non-OECD nations.

### *Non-OECD Asia*

Much of the growth in non-OECD (and world) transportation energy use occurs in the emerging economies of non-OECD Asia. In particular, China accounts for the world's largest regional increment in transportation energy use, adding 14.3 quadrillion Btu of consumption over the 2012–40 projection period. China's consumption of transportation fuels increases on average by 2.7%/year from 2012 to 2040 (Figure 8-4), led by increases of 3.0%/year for heavy-duty vehicles that amount to 34% of the country's total increase in transportation sector energy consumption. Although energy consumption by light-duty vehicles increases by a more robust 3.5%/year, they account for only 27% of China's total increase in transportation fuel use.

Total transportation energy consumption in India also shows substantial growth in the IEO2016 Reference case, from 3.3 quadrillion Btu in 2012 to 10.9 quadrillion Btu in 2040, for an average annual increase of 4.4%. Fuel consumption by India's light-duty vehicles grows by 7.7%/year, accounting for 51% of the total increase in transportation energy use, largely as the result of a sizable increase in the country's middle class. Energy use by heavy-duty vehicles increases by an average of 4.4%/year from 2012 to 2040 and accounts for 18% of the total increase in India's transportation energy use.

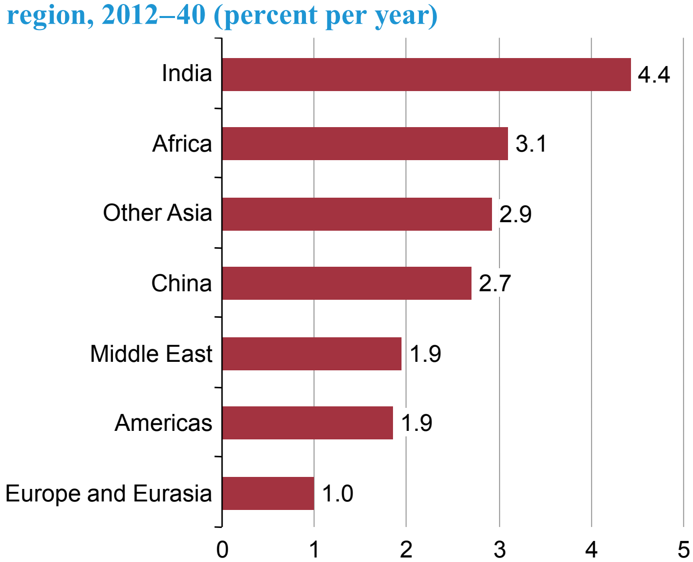
Like India and China, the other economies of non-OECD Asia also show significant growth in transportation energy demand from 2012 to 2040 in the IEO2016 Reference case. Total transportation energy consumption among the other non-OECD Asia nations grows from 7.6 quadrillion Btu in 2012 to 17.0 quadrillion Btu by 2040 in the Reference case, averaging 2.9%/year, with light-duty vehicle energy consumption rising by an average of 3.9%/year and accounting for 51% of the total increase in transportation energy consumption among the non-OECD Asian nations other than China and India. Significant increases in transportation energy use in these other non-OECD Asia nations are also projected for airline travel (17% of the total increase) and for heavy-duty trucks (7%).

### *Other non-OECD*

Although the largest expansion in non-OECD transportation energy use occurs in non-OECD Asia, substantial increases are also projected for Africa, the Middle East, and the non-OECD Americas. In Africa, for instance, transportation energy consumption increases from 4.3 quadrillion Btu in 2012 to 10.1 quadrillion Btu by 2040, averaging 3.1%/year. On a regional basis, Africa has the world's highest projected growth in population (2.1%/year from 2012 to 2040) and robust projected growth in income (GDP rises by 4.8%/year). These demographic trends, combined with an underdeveloped transportation sector, explain the strong increase in transportation energy demand in the IEO2016 Reference case. The consumption of light-duty vehicle fuels increases by 3.9%/year in Africa, accounting for 52% of total transportation energy use in the region, as a result of a substantial increase in the number of middle-class consumers. Energy consumed by heavy-duty trucks increases by an average of 2.5%/year and accounts for 5% of Africa's total increase in transportation energy consumption.

In the non-OECD Americas, growth in transportation energy use is slower than in the non-OECD as a whole. In particular, transportation energy consumption in Brazil—the largest economy in the non-OECD Americas—increases by an average of 1.7%/year from 2012 to 2040, compared to the 2.5%/year increases projected for the non-OECD region as a whole. Fuel consumption in light-duty vehicles and heavy-duty trucks grows by similar rates in Brazil, with light-duty vehicles accounting for 31% of the total increase and heavy-duty trucks for 14%.

**Figure 8-4. Average annual growth in delivered transportation energy consumption by non-OECD region, 2012–40 (percent per year)**




## Transportation sector energy consumption by mode

The transportation sector comprises both passenger and freight modes. The passenger modes include light-duty cars and trucks, buses, 2- and 3-wheel vehicles, airplanes, and passenger trains. The freight modes, which are used in the movement of raw, intermediate, and finished goods to consumers, include trucks (heavy-, medium-, and light-duty), marine vessels (international and domestic), rail, and pipelines.

Passenger or personal mobility-related fuel consumption accounted for 61% of total world transportation energy consumption in 2012. Among the personal mobility modes of transport, light-duty vehicles accounted for 44% of total world transportation energy use, followed by aircraft at 11%. Buses, 2- and 3-wheel vehicles, and rail accounted for 6% of total world transportation energy use. Freight modes accounted for the other 39% of total world transportation energy consumption. Freight trucks made up by far the largest share (23%) of total transportation energy use, followed by marine vessels (12%) and rail and pipelines (a combined 4%).

Worldwide, projected energy consumption for all transportation modes grows from 2012 to 2040. For passenger travel modes, total energy consumption rises by an average of 1.4%/year, from 63 quadrillion Btu in 2012 to 94 quadrillion Btu in 2040 (Figure 8-5). Light-duty vehicles show the largest absolute increase (15 quadrillion Btu) from 2012 to 2040 among the passenger modes of travel but the slowest growth (1.0%/year) among all the transport modes. World energy demand for aircraft increases by a total of 10 quadrillion Btu from 2012 to 2040, while the combined energy demand for buses, 2- and 3-wheel vehicles, and rail grows by 6 quadrillion Btu.

Total freight-related energy consumption grows by an annual average of 1.5% in the IEO2016 Reference case, from 40 quadrillion Btu in 2012 to 60 quadrillion Btu in 2040 (Figure 8-6)—slightly faster than the passenger modes. Energy consumption for freight trucks increases by a total of 13 quadrillion Btu from 2012 to 2040, followed by marine vessels at 6 quadrillion Btu and rail and pipelines combined at about 2 quadrillion Btu. The U.S. Environmental Protection Agency recently proposed a significant increase in fuel economy standards for heavy trucks. Should these proposed standards be adopted as final rules, they could significantly lower projections for diesel use in trucking. To the extent that these standards are implemented and affect trucks sold throughout the world, the reduction in diesel fuel use in trucking could be greatly magnified.

The growth trends for energy consumed by passenger modes in OECD and non-OECD regions from 2012 to 2040 differ considerably in the IEO2016 Reference case (Figure 8-7), with the OECD total declining by 1 quadrillion Btu and the non-OECD total increasing by 31 quadrillion Btu. The difference is explained in part by the larger increase in non-OECD passenger travel per capita from a low average base relative to most OECD nations. Non-OECD income (as measured by GDP) grows at a faster rate than in the OECD economies, and non-OECD consumers use more personal transportation as per-capita incomes grow. Although incomes also rise in the OECD nations, OECD levels of personal mobility are already relatively high, and transportation patterns and infrastructure are well established. In addition, the effects of increases in personal travel on OECD transportation energy consumption are tempered by rising energy efficiency, resulting in no growth in transportation energy consumption (see Figure 8-1). Although energy efficiency improvements also occur in the non-OECD regions, their impacts are overwhelmed by the increases in personal incomes and travel demand.

**Figure 8-5. World transportation sector delivered energy consumption by passenger modes, 2012 and 2040 (quadrillion Btu)**

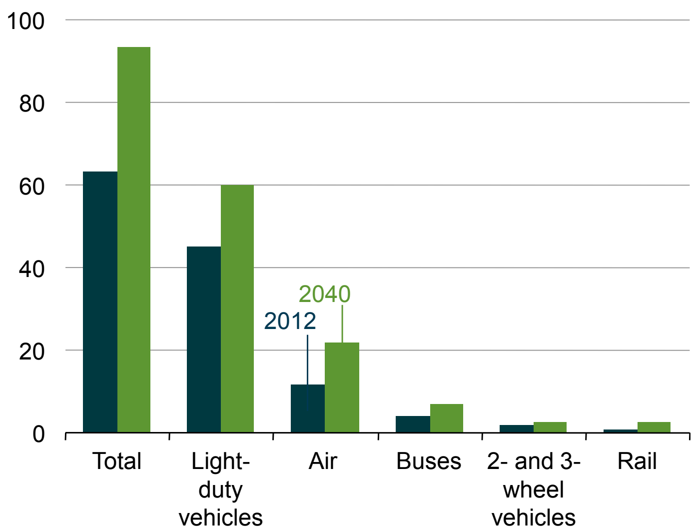



**Figure 8-6. World transportation sector delivered energy consumption by freight modes, 2012 and 2040 (quadrillion Btu)**

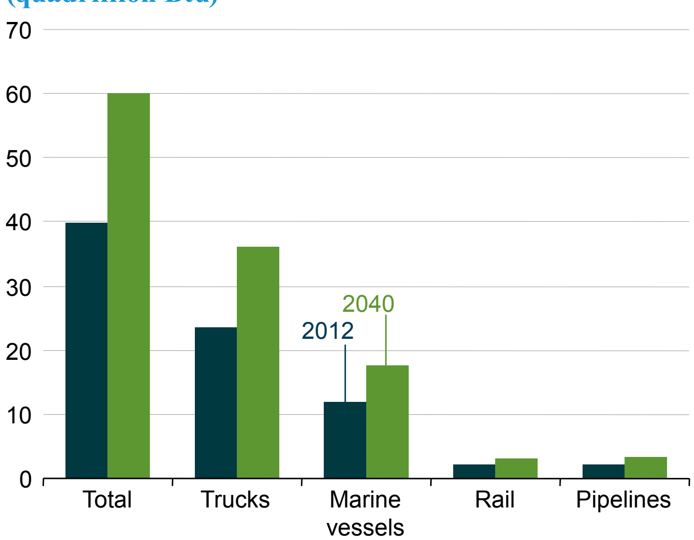
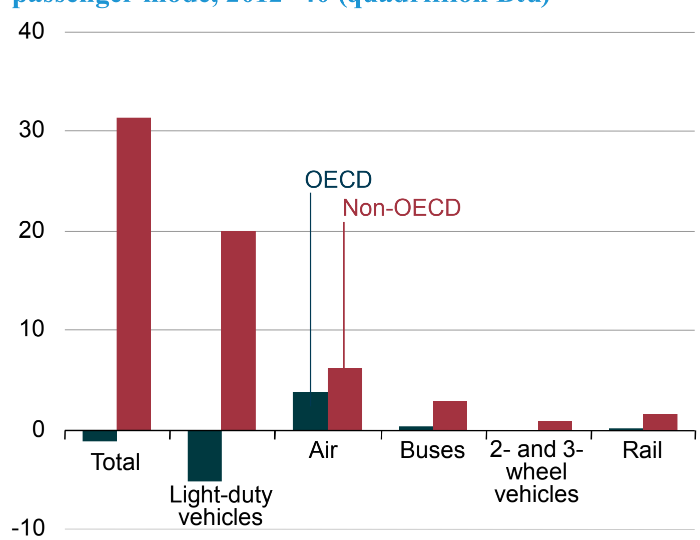



**Figure 8-7. Change in OECD and non-OECD delivered transportation energy consumption by passenger mode, 2012–40 (quadrillion Btu)**



## World transportation energy use for passenger travel

The transportation of people and goods accounts for about 25% of total world delivered energy consumption (Figure 8-8). Passenger transportation—in particular, light-duty vehicles—accounts for most transportation energy consumption, with light-duty vehicles consuming more energy than all modes of freight transportation, including heavy trucks, marine, and rail combined.

The United States, where on-road passenger travel is especially prevalent, was the world's largest transportation energy consumer in 2012, the most recent year for which detailed international transportation data are available by mode. The United States consumed 26 quadrillion Btu of transportation energy in 2012, or 13 million barrels of oil equivalent per day (b/d), representing 25% of global transportation energy demand.

Major European countries (those in the OECD) and China are also major transportation energy consumers, at 19 quadrillion Btu and 13 quadrillion Btu, respectively, in 2012. In contrast to both the United States and OECD Europe, the largest share of China's on-road transportation energy use is for freight movement rather than passenger travel. Together, the United States, OECD Europe, and China account for 55% of world transportation energy consumption (Figure 8-9).

On-road use accounts for the largest share of transportation energy consumption in all regions of the world, but there is considerable variation across regions in the use of other modes of transportation. For instance, marine transport accounts for one-fourth of South Korea's total transportation energy use, reflecting the importance of marine transport in a peninsula nation whose economy relies heavily on exports, with major trading partners reached by maritime travel. In Australia, where regional air travel helps connect coastal population centers with sparsely populated regions, interior air travel accounts for nearly 20% of total transportation energy consumption, compared with 9% in the United States and 6% in China.

Global transportation energy consumption is dominated by two fuels: motor gasoline (including ethanol blends) and diesel (including biodiesel blends). Together, these two fuels accounted for 75% of total delivered transportation energy use in 2012. Motor gasoline is used primarily for the movement of people, especially by light-duty vehicles. Diesel fuel is used primarily for the movement of goods, especially by heavy-duty trucks. Jet fuel accounts for 12% of the world's transportation energy consumption, followed by residual fuel oil at 9%. Petroleum products account for the largest share of transportation energy use by far, while nonpetroleum fuels account for a small portion of the world energy mix, with natural gas and electricity together accounting for about 4% of the world's total transportation energy consumption.

**Figure 8-8. World transportation energy consumption by mode, 2012 (quadrillion Btu)**

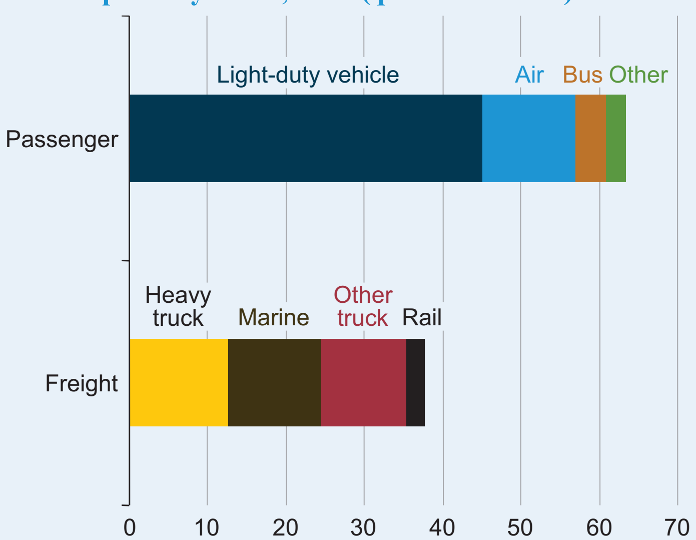
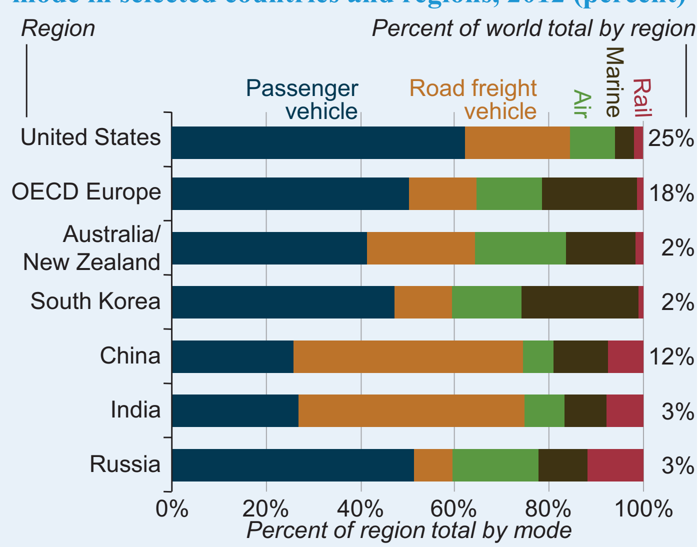



**Figure 8-9. Transportation energy consumption by mode in selected countries and regions, 2012 (percent)**

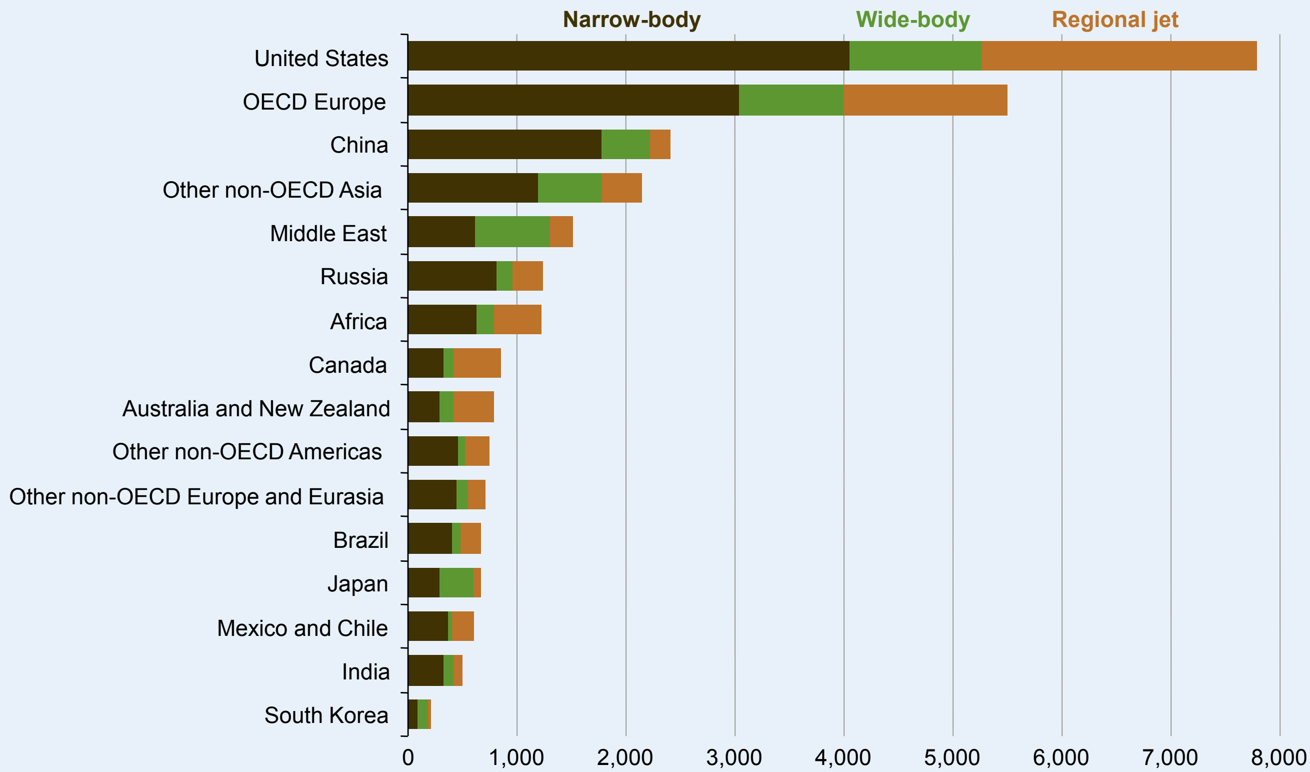



By mode, the largest increases in annual energy consumption for non-OECD passenger travel from 2012 to 2040 in the Reference case are for light-duty vehicles (20 quadrillion Btu) and aircraft (6 quadrillion Btu). In contrast, OECD energy demand for light-duty vehicles declines by 5 quadrillion Btu from 2012 to 2040, and annual energy demand for aircraft grows by only 4 quadrillion Btu.

## World stocks of passenger jet aircraft

In 2013, three types of jet aircraft stock were available for national and international passenger travel: narrow-body, wide-body, and regional. Narrow-body jets are designed to carry between 120 and 180 passengers in two banks of seats separated by a center aisle; wide-body jets are designed for 200 to 500 passengers in three banks of seats; and regional jets are designed for 50 to 110 passengers. Nearly 28,000 passenger jets were in service in 2013, of which 55% were narrow-body, 19% were wide-body, and 26% were regional jets. By region, the United States had the largest stock of passenger jets (7,800), and OECD Europe had the second-largest (5,500). India and South Korea had the smallest numbers of passenger jets (499 and 209, respectively) (Figure 8-10).

### Figure 8-10. World passenger jet aircraft stocks by region and type, 2013

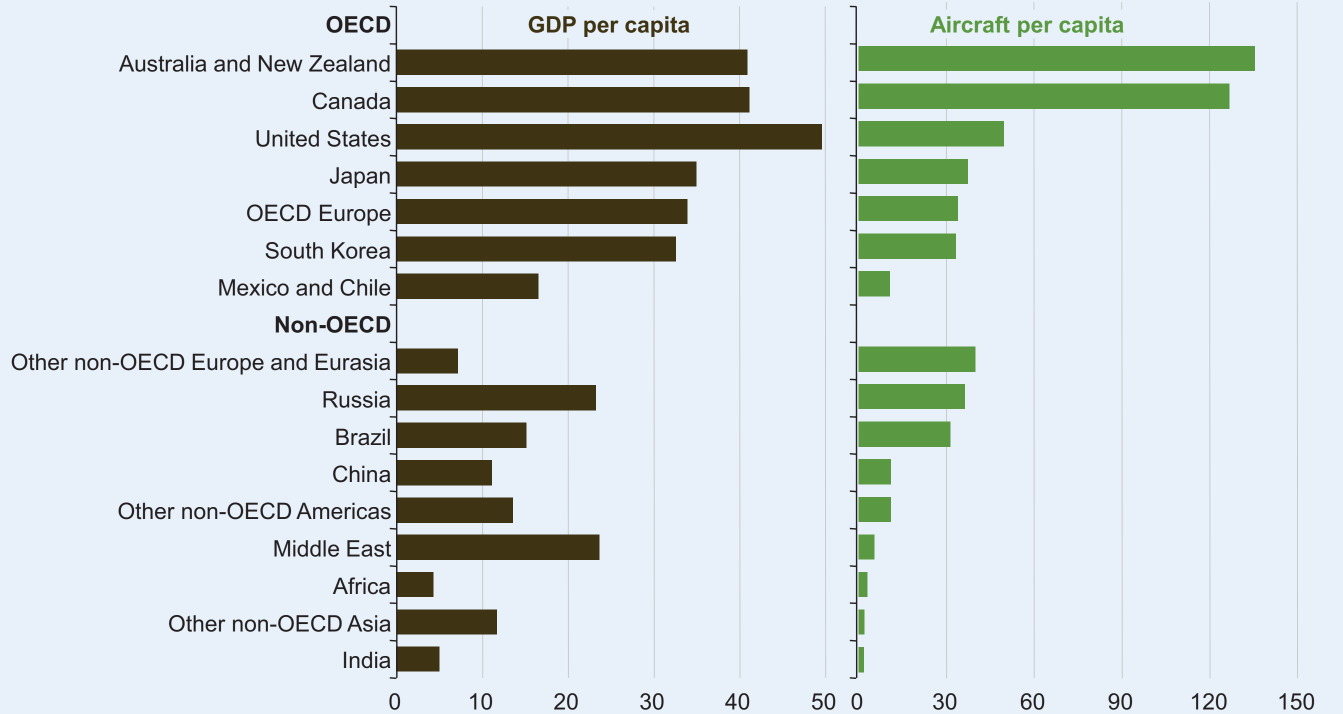



In most regions, narrow-body aircraft used for regional and transcontinental trips account for more than half of total aircraft fleets. In other regions—including the Middle East, Japan, and South Korea—air travel is dominated by long international flights, and wide-body aircraft account for approximately 45% of the totals. In regions where short-range trips are more prevalent, regional jets make up the largest shares of aircraft fleets, including 46% in Australia/New Zealand and 51% in Canada.

Ratios of aircraft stock per million people also differ by region. In general, the more developed OECD regions, with higher gross domestic product (GDP) per capita, also have higher aircraft-to-population ratios than the non-OECD regions (Figure 8-11). The Australia/New Zealand region has the world's highest aircraft-to-population ratio (136 aircraft per million people), Canada has the second-highest (127), and the United States has the third-highest (50) despite its higher GDP per capita. In Japan (with GDP per capita of $35,000), the ratio of aircraft per million population is estimated at 37, while for Canada (with GDP per capita of $41,000), the ratio is estimated at 127. Africa, India, and other non-OECD Asia have the lowest aircraft-to-population ratios at 3, 2, and 2, respectively. These numbers underscore the significant uncertainty associated with projecting future trajectories of aircraft-to-population ratios in non-OECD countries as they develop economically, which may reflect regional characteristics such as geography and population despite having similar GDP per capita.

*(continued on page 133)*

**Figure 8-11. Gross domestic product (thousand 2010 dollars per person) and aircraft stock per capita (aircraft per million people) by region, 2013**




In contrast to passenger modes of travel, the trends in freight modes in the OECD and non-OECD regions are similar (Figure 8-12). In both, energy consumption increases for all freight modes from 2012 to 2040, with the largest increases for trucks and international maritime vessels. Production and consumption of goods worldwide are an integral part of globalized supply chains, including trade in intermediate products for global production processes, which in large part is made possible by containerized transportation shipping and advances in information technology.

## Transportation sector travel demand

Rising global incomes increase the demand for personal mobility, measured as passenger-miles per capita, in all the world regions, with different rates of increase depending on current income levels (Figure 8-13) and travel patterns, as well as the unique nature of regional geographies. Consequently, the rates of increase in travel demand per capita vary across the OECD and non-OECD regions (Figure 8-14).

**Figure 8-12. Change in OECD and non-OECD delivered transportation energy consumption by freight mode, 2012–40 (quadrillion Btu)**

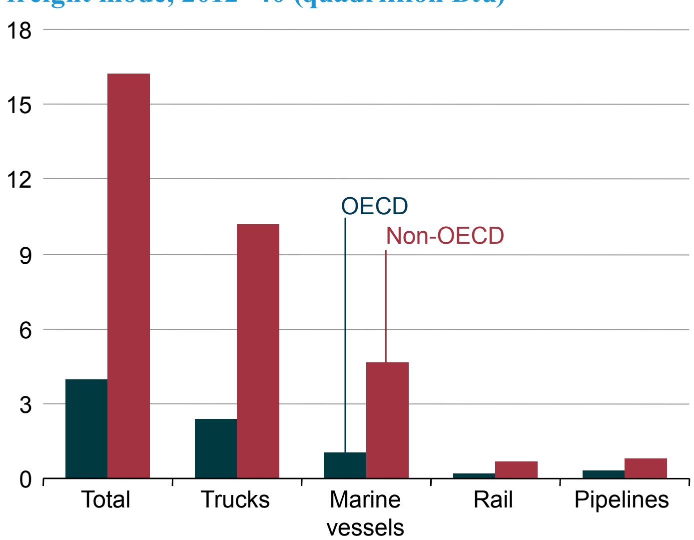
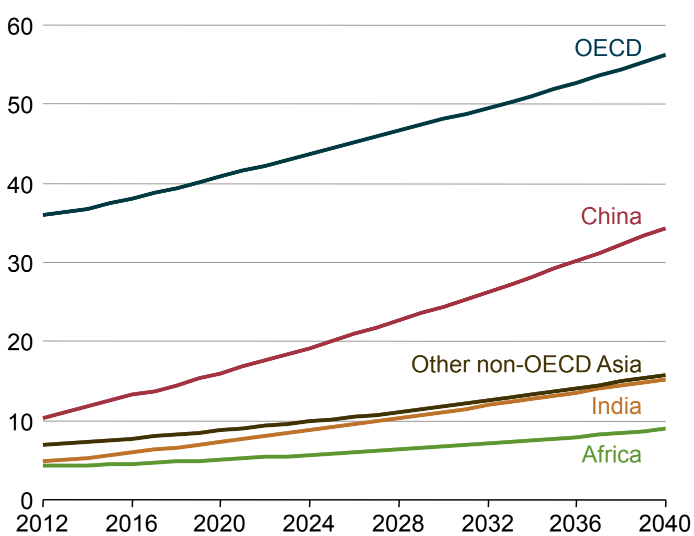



**Figure 8-13. GDP per capita in selected regions and countries, 2012–40 (thousand 2010 dollars)**



OECD regions are, for the most part, economically developed and thus have higher levels of personal mobility than the non-OECD countries. In the IEO2016 Reference case, OECD passenger travel per capita (including light-duty and 2- and 3-wheel vehicles, buses, and passenger rail but excluding aircraft) increases from 9.1 thousand passenger-miles/person in 2012 to 10.3 thousand passenger-miles/person in 2040, while average GDP per capita rises from about $36,000/person to $56,500/person (in inflation-adjusted real 2010 U.S. dollars). In comparison, average non-OECD GDP per capita rises from an average of $8,500/person in 2012 to $20,800/person in 2040, and passenger travel per capita rises from 2.1 thousand passenger-miles/person in 2012 to 4.9 thousand passenger-miles/person in 2040.

As a result of the increase of more than 100% in non-OECD travel demand from 2012 to 2040, the region's total energy use for passenger travel in 2040 is more than 50% higher than the OECD total, compared with about two-thirds the OECD total in 2012. In 2012, non-OECD Asia (including China and India) and Africa accounted for two-thirds of the world's total population; in 2040, they are projected to account for more than 70%. Accordingly, the two regions have the largest projected growth in transportation energy consumption in the IEO2016 Reference case. In China, delivered energy consumption in the transportation sector increases by 2.7%/year from 2012 to 2040, compared with 0.2%/year for the OECD as a whole. Per-capita income in China in 2040 is similar to the OECD level in 2012, but China's transportation sector delivered energy consumption in 2040, at 18.9 million Btu/person, is less than half the OECD's 2012 average of 46.2 million Btu/person.

The transportation modes used for passenger travel also reflect the effects of rising incomes and the current difference between OECD and non-OECD personal mobility choices. In 2012, more than 80% of OECD personal travel was by light-duty vehicle, compared with 41% of non-OECD personal travel. In the non-OECD region, a substantial portion of personal travel was by bus (35%), passenger rail (13%), and 2- and 3-wheeled vehicles (11%). Non-OECD economic growth and rising incomes in the IEO2016 Reference case lead to a higher overall rate of light-duty vehicle ownership (measured as the number of light-duty vehicles per 1,000 people), but in 2040 the non-OECD rate of light-duty vehicle ownership remains well below the OECD rate (Figure 8-15). Still, the light-duty vehicle share of non-OECD passenger travel rises to more than 50% in 2040, primarily at the expense of buses and 2- and 3-wheeled vehicles (Figure 8-16). Consequently the difference in light-duty vehicle travel shares between the OECD and non-OECD regions is narrowed, but not eliminated, by 2040 in the Reference case.

Demand for personal travel by aircraft, measured as revenue passenger-miles, shows a similar trend. As GDP and personal incomes increase, business and personal airline travel also increase. Relatively wealthy OECD consumers already have a much higher rate of airline travel per capita than do non-

**Figure 8-14. Passenger travel per capita in selected regions and countries, 2012–40 (thousand passenger-miles)**

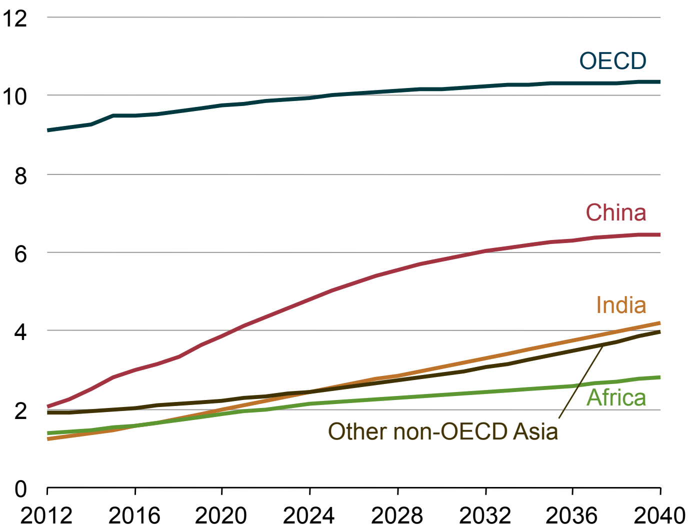



**Figure 8-15. Light-duty vehicles per thousand people in selected regions and countries, 2012–40**

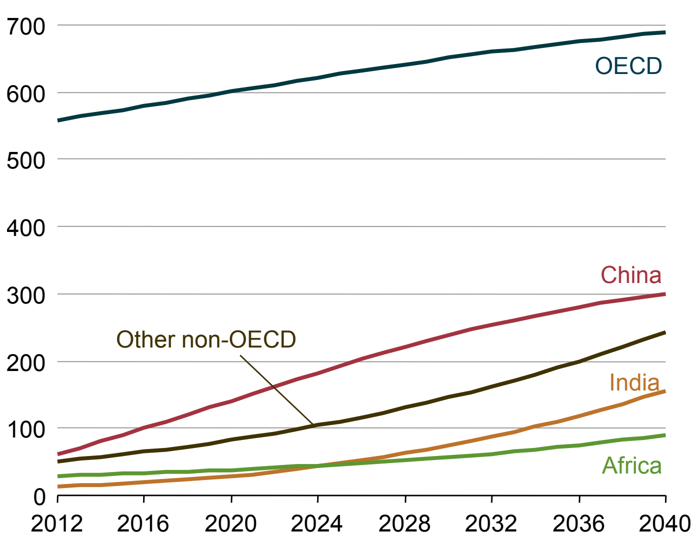
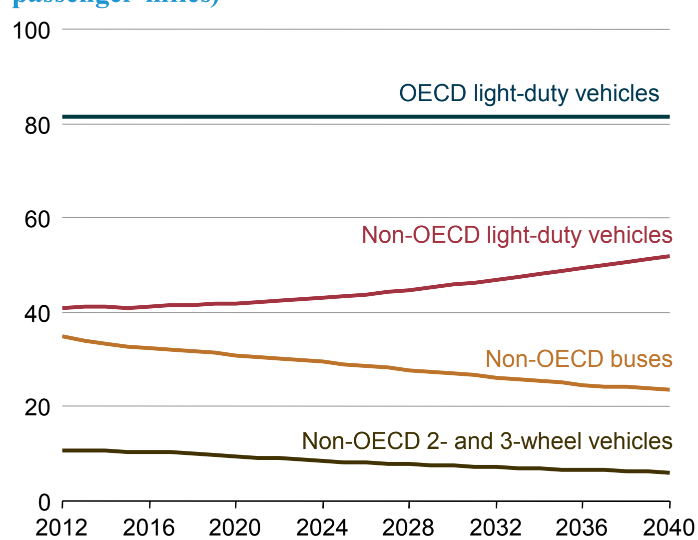



**Figure 8-16. OECD and non-OECD passenger travel by selected travel modes, 2012–40 (percent of total passenger-miles)**

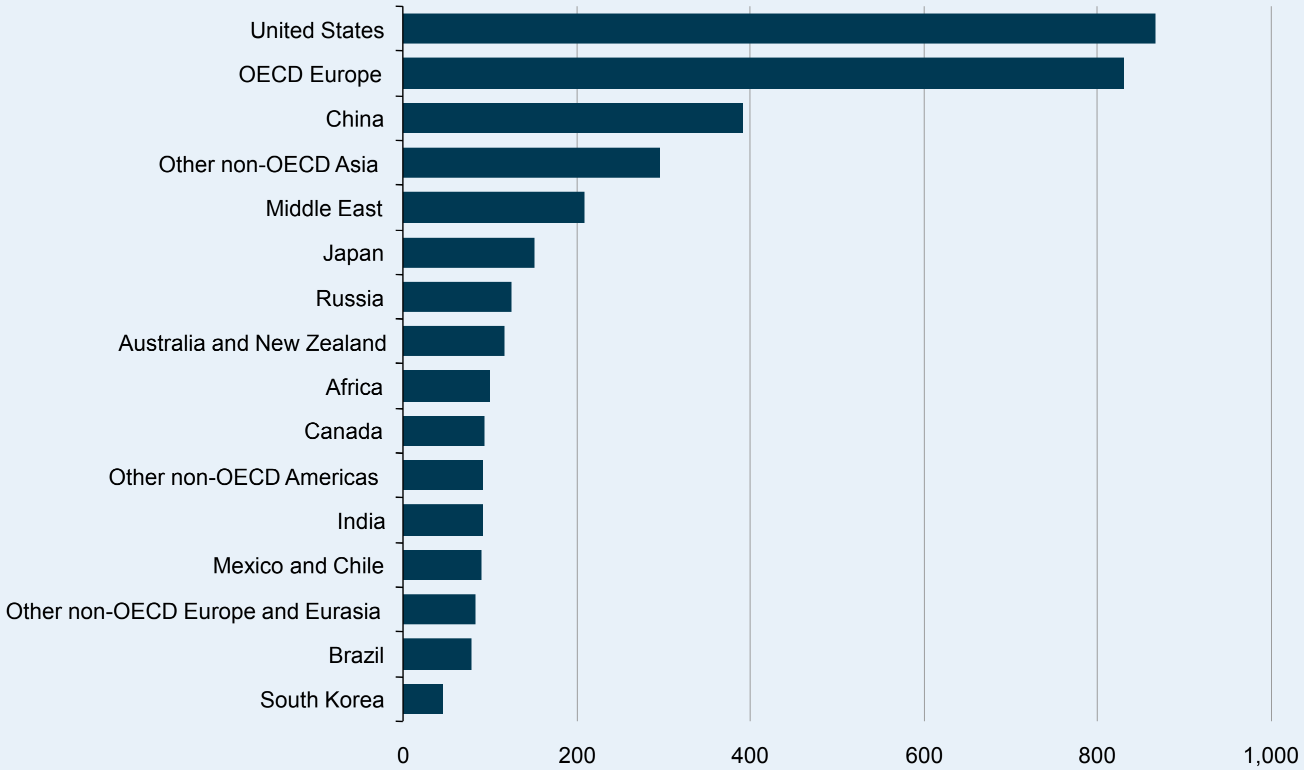


OECD consumers. Demand for airline travel increases in the Reference case for both the OECD and non-OECD regions, with more rapid growth among the non-OECD regions.

## Variations in air passenger travel by region and income level

Air passenger travel, measured by revenue passenger-miles (RPM),[327] includes both domestic travel (within a single IEO2016 region) and international travel (across regional boundaries). In 2013, the United States led the other world regions in total passenger air travel with 866 billion RPM, followed by OECD Europe with 830 billion RPM and China with 392 billion RPM. South Korea had the lowest passenger air travel, at 47 billion RPM (Figure 8-17).

**Figure 8-17. World air passenger travel by region, 2013 (billion revenue passenger-miles)**




In 2013, the United States had the world's highest level of domestic air passenger travel and the second-highest level of international air passenger travel, at 603 billion RPM and 264 billion RPM, respectively. OECD Europe, with the second-highest level of domestic air passenger travel, at 435 billion RPM, was first in international travel with 395 billion RPM. China was third in domestic air passenger travel, at 281 billion RPM, and other non-OECD Asia was third in international air travel, at 170 billion RPM (Figure 8-18).

As gross domestic product (GDP) per capita increases in the world regions, RPM per capita also increases. Regions with the highest GDP per capita (United States, Australia/New Zealand, and Canada) also have the highest RPM per capita. In 2013, Australia led the world with 4,200 RPM per capita, followed by the United States and Canada, both with 2,700 RPM per capita. Regions with lower GDP per capita also have lower RPM per capita (Figure 8-19). India and Africa had the lowest GDP per capita in 2013 ($5,000 and $4,300, respectively) and the lowest rates of personal air travel (less than 100 RPM per capita).

In general, regions with higher GDP per capita have higher RPM per capita. The regions with the world's top five highest RPM per capita are comparatively wealthy OECD regions—the United States, Australia and New Zealand, Canada, OECD Europe, and Japan. Most of the non-OECD regions have RPM per capita below 500. In the coming years, as strong economic growth in many non-OECD regions results in higher GDP per capita, personal air travel also is expected to rise, as suggested by the trends shown in Figure 8-19. As average GDP per capita in the non-OECD regions approaches $40,000, travel behavior can be expected to vary—as it has in the OECD regions—adding uncertainty as to whether future trends in RPM per capita for the non-OECD regions will more closely resemble RPM per capita for Australia or for the United States.

*(continued on page 136)*

[327] The value for revenue passenger-miles is calculated as: *(number of revenue-paying passengers) × (total miles traveled).*

**Figure 8-18. World domestic and international air passenger travel by region, 2013 (billion revenue passenger-miles)**

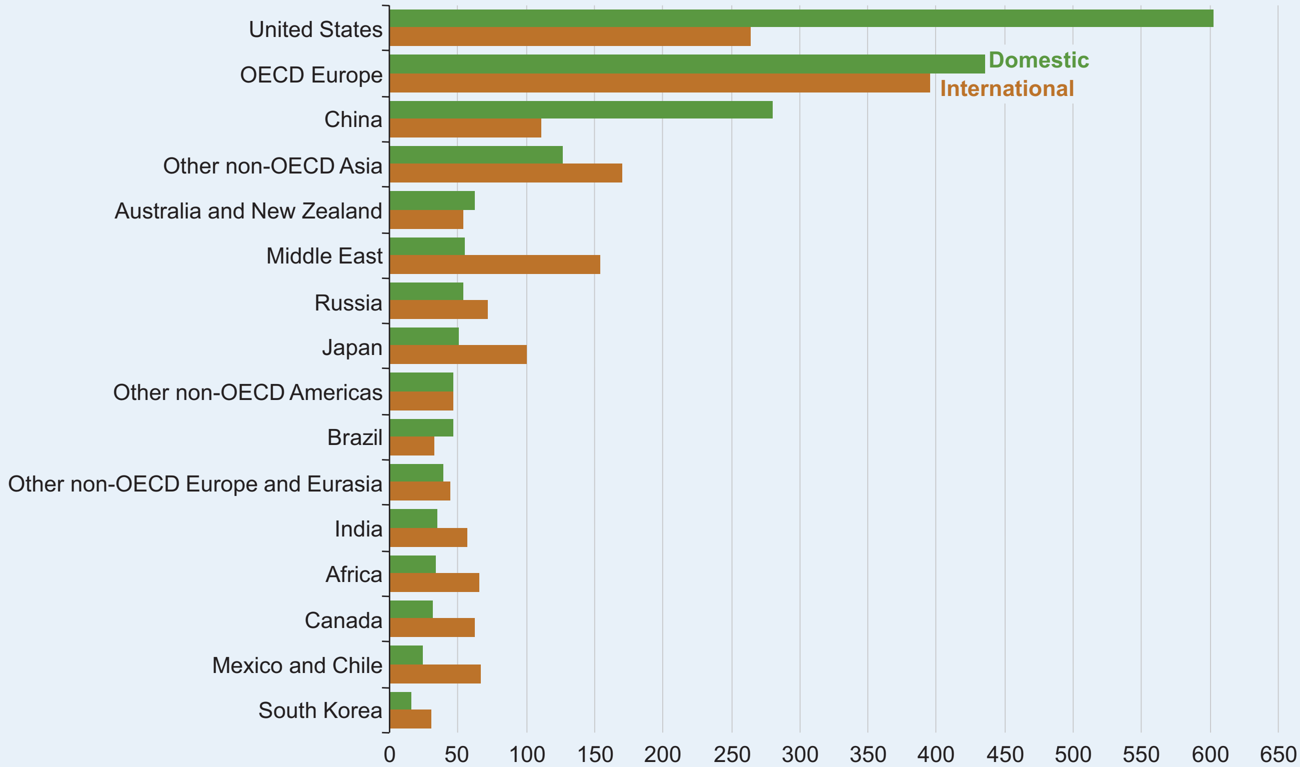
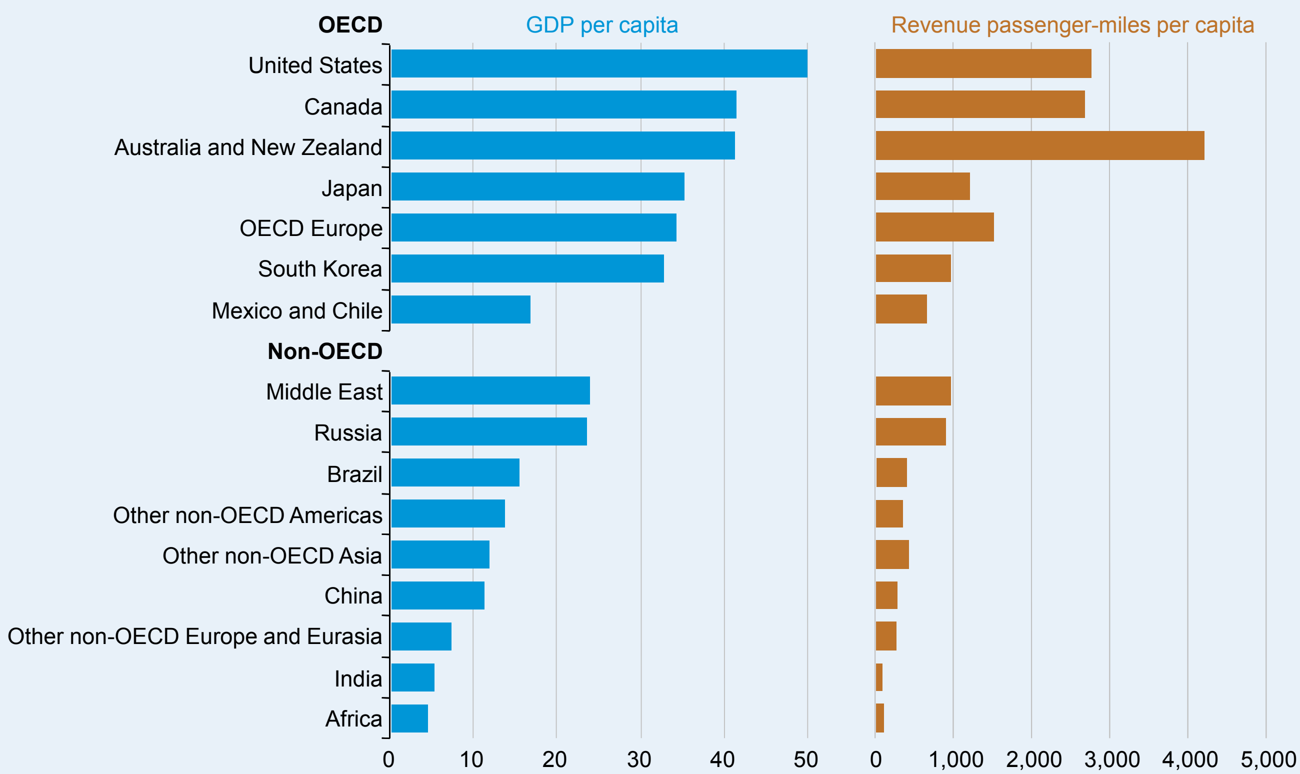



**Figure 8-19. OECD and non-OECD gross domestic product per capita (thousand 2010 dollars) and air passenger travel per capita (revenue passenger-miles) by region, 2013**



The movement of freight (including trucks, rail, and domestic marine vessels), measured in ton-miles,[328] also shows the impact of economic growth. Freight travel demand is related explicitly to economic activity, including the production and consumption of goods in either intermediate or final form. Non-service industrial gross output[329] per capita and GDP per capita can be used as proxies for production and intermediate and personal consumption. As these two measures increase, the number of freight ton-miles per capita increases. For example, in the IEO2016 Reference case, OECD nonservice industrial gross output per capita increases from about $24,000/person in 2012 to $37,000/person in 2040 (Figure 8-20), and ton-miles per capita increases from about 6.0 thousand ton-miles/person in 2012 to 9.0 thousand ton-miles/person in 2040 (Figure 8-21). Similarly, non-OECD non-service industrial output per capita grows from $10,000/person to $22,000/person, and ton-miles per capita increases from about 2.0 thousand ton-miles in 2012 to 4.0 thousand ton-miles in 2040.

Another source of freight energy consumption is international marine vessels. Worldwide economic growth from the production and consumption of goods, as well as consumption of energy commodities, leads directly to growth in worldwide volumes of maritime freight movement. Approximately 80% of the world's merchandise trade by volume is carried over water, with maritime trade in 2012 totaling nearly 60 trillion ton-miles.[330] Because of globalized supply chains, maritime shipments of nonenergy commodities, such as manufactured goods, agricultural products, and minerals, have grown much faster than global GDP and accounted for approximately 60% of total maritime freight movement in in 2012. Significant amounts of energy commodities, such as crude oil from the Middle East and coal from Australia, also are transported internationally by cargo ships.

**Figure 8-20. OECD and non-OECD industrial gross output per capita, excluding service industries, 2012–40 (thousand 2010 dollars)**

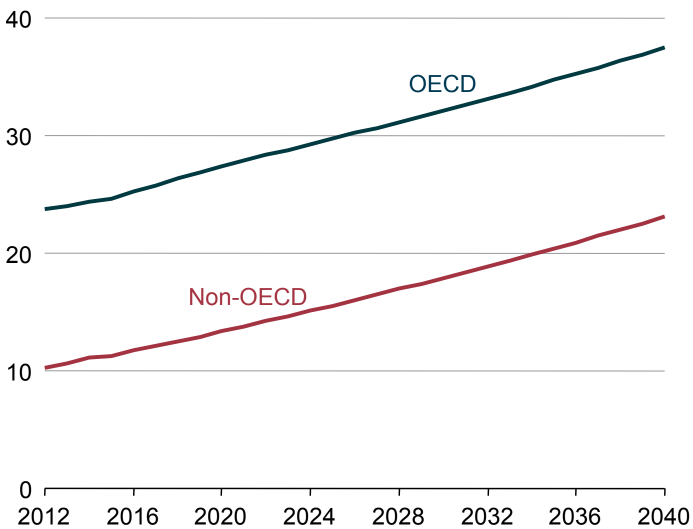
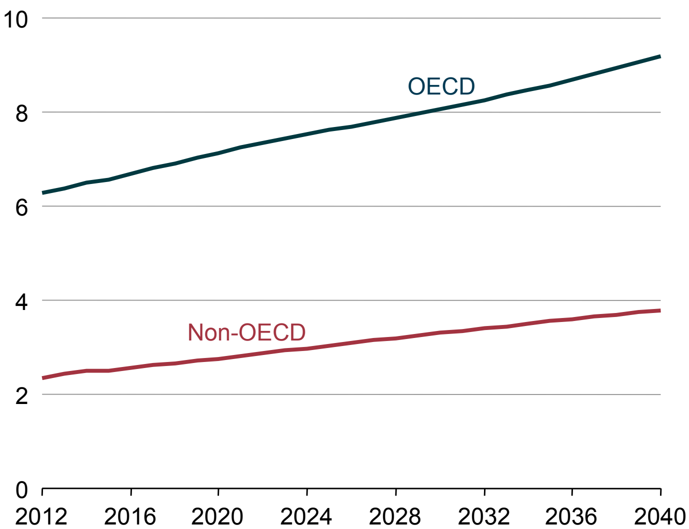



**Figure 8-21. OECD and non-OECD freight movement per capita by truck, rail, and domestic marine vessels, 2010–40 (thousand ton-miles)**




[328]Ton-mile is a common measure of freight movement, defined as the product of tons and miles, taking into account both distance moved and weight. For example, 100 ton-miles may be 1 ton of freight moved 100 miles or 100 tons of freight moved 1 mile.

[329]The nonservice industrial sector includes agriculture, construction, mining, and manufacturing.

[330]United Nations, Development Policy and Analysis Division, *World Economic Situation and Prospects 2012,* Chapter 2 (New York, NY: 2012), p. 44, http://www.un.org/en/development/desa/policy/wesp/wesp_archive/2012chap2.pdf.

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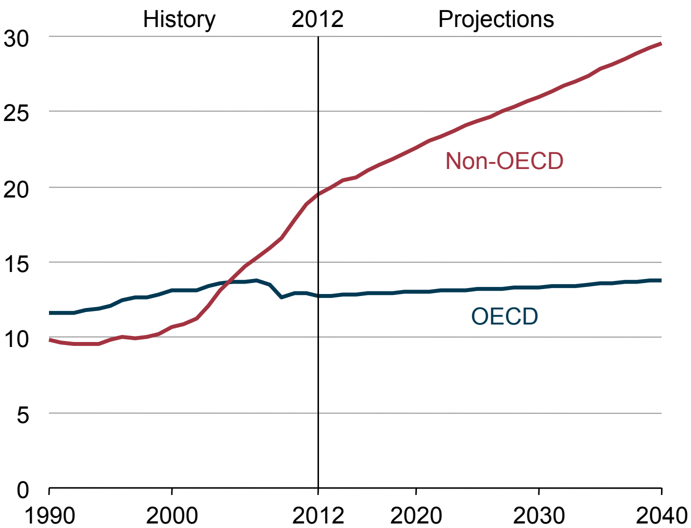
Chapter 9

# Energy-related CO2 emissions

## Overview

Because anthropogenic emissions of carbon dioxide (CO2) result primarily from the combustion of fossil fuels, energy consumption is at the center of the climate change debate. In the *International Energy Outlook 2016* (IEO2016) Reference case, world energy-related CO2 emissions[331] increase from 32.3 billion metric tons in 2012 to 35.6 billion metric tons in 2020 and to 43.2 billion metric tons in 2040. The Reference case estimates do not include effects of the recently finalized Clean Power Plan (CPP) regulations in the United States, which reduce projected U.S. emissions in 2040 by 0.5 billion metric tons. Much of the growth in emissions is attributed to developing nations outside the Organization for Economic Cooperation and Development (OECD), many of which continue to rely heavily on fossil fuels to meet the fast-paced growth of energy demand. In the IEO2016 Reference case, non-OECD emissions in 2040 total 29.4 billion metric tons, or about 51% higher than the 2012 level. In comparison, OECD emissions total 13.8 billion metric tons in 2040, or about 8% higher than the 2012 level (Table 9-1 and Figure 9-1).

**Figure 9-1. OECD and non-OECD energy-related carbon dioxide emissions, 1990–2040 (billion metric tons)**




In conjunction with the 21st Conference of Parties in Paris (COP21, November 30 through December 12, 2015), many countries have submitted emissions reduction goals, or Intended Nationally Determined Contributions (INDCs), under the United Nations Framework Convention on Climate Change (UNFCC) *(see "Policies to limit CO2 emissions in the United States and China," below)*. EIA has tried to incorporate

**Table 9-1. World energy-related carbon dioxide emissions by fuel type, 1990–2040 (billion metric tons)**

| Region/Country | 1990 | 2012 | 2020 | 2030 | 2040 | Average annual percent change, 2012–40 | Total change, 2012–40 (billion metric tons) | Percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OECD** | **11.6** | **12.8** | **13.0** | **13.3** | **13.8** | **0.3** | **1.0** | **8** |
| Liquid fuels | 5.5 | 5.7 | 5.6 | 5.5 | 5.6 | -0.1 | -0.2 | -3 |
| Natural gas | 2.0 | 3.1 | 3.3 | 3.8 | 4.2 | 1.1 | 1.1 | 35 |
| Coal | 4.1 | 3.9 | 4.1 | 4.1 | 4.0 | 0.1 | 0.1 | 2 |
| **OECD with CPP** | **11.6** | **12.8** | **12.7** | **12.7** | **13.3** | **0.1** | **0.5** | **4** |
| Liquid fuels | 5.5 | 5.7 | 5.6 | 5.5 | 5.5 | -0.1 | -0.2 | -3 |
| Natural gas | 2.0 | 3.1 | 3.4 | 3.8 | 4.2 | 1.0 | 1.1 | 34 |
| Coal | 4.1 | 3.9 | 3.7 | 3.5 | 3.5 | -0.4 | -0.4 | -10 |
| **Non-OECD** | **9.9** | **19.5** | **22.6** | **25.8** | **29.4** | **1.5** | **9.9** | **51** |
| Liquid fuels | 3.6 | 6.0 | 7.3 | 8.5 | 10.0 | 1.9 | 4.0 | 67 |
| Natural gas | 2.0 | 3.4 | 4.0 | 5.4 | 6.9 | 2.5 | 3.5 | 102 |
| Coal | 4.2 | 10.1 | 11.3 | 11.9 | 12.5 | 0.8 | 2.4 | 24 |
| **World** | **21.4** | **32.3** | **35.6** | **39.1** | **43.2** | **1.0** | **10.9** | **34** |
| Liquid fuels | 9.1 | 11.7 | 12.9 | 14.0 | 15.5 | 1.0 | 3.8 | 33 |
| Natural gas | 4.0 | 6.6 | 7.3 | 9.2 | 11.2 | 1.9 | 4.6 | 70 |
| Coal | 8.4 | 14.0 | 15.4 | 15.9 | 16.5 | 0.6 | 2.5 | 18 |
| **World with CPP** | **21.4** | **32.3** | **35.3** | **38.5** | **42.7** | **1.0** | **10.4** | **32** |
| Liquid fuels | 9.1 | 11.7 | 12.9 | 14.0 | 15.5 | 1.0 | 3.8 | 33 |
| Natural gas | 4.0 | 6.6 | 7.4 | 9.2 | 11.1 | 1.9 | 4.6 | 70 |
| Coal | 8.4 | 14.0 | 15.0 | 15.3 | 16.0 | 0.5 | 2.0 | 14 |

[331] In IEO2016, energy-related CO2 emissions are defined as emissions related to the combustion of fossil fuels (liquid fuels, natural gas, and coal) and emissions associated with petroleum feedstocks. Emissions from the flaring of natural gas are not included.

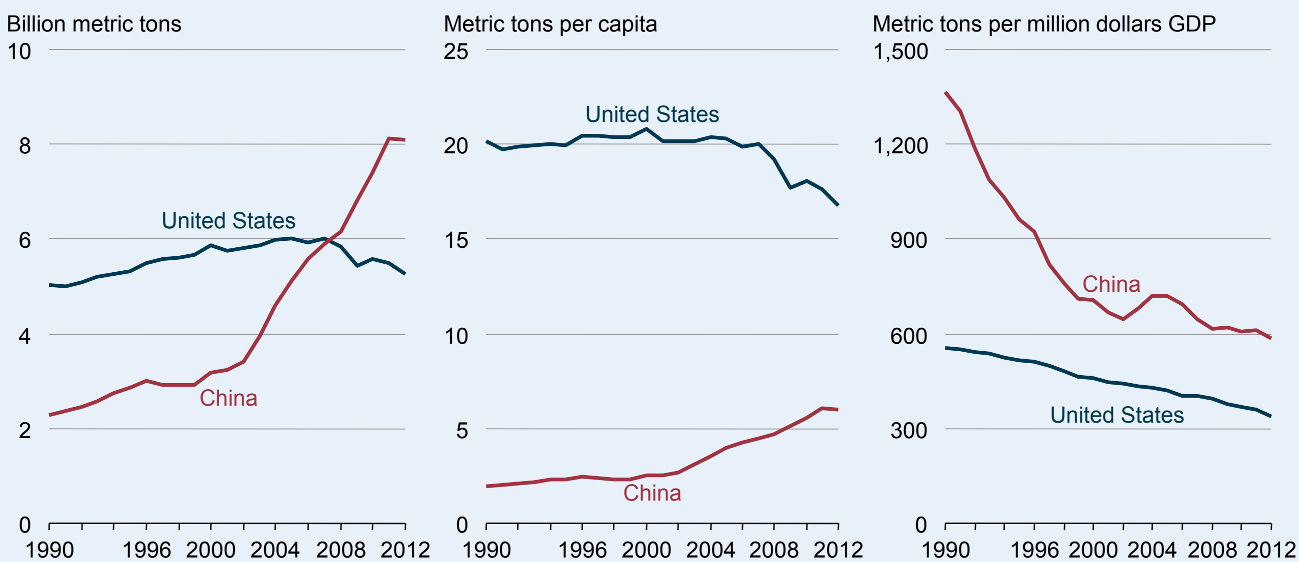
some of the specific details, such as renewable energy goals, in the IEO2016 Reference case; however, a great deal of uncertainty remains with regard to the implementation of policies to meet stated goals. In addition, beyond energy-related CO2, other gases (e.g., methane) and sources (e.g., deforestation) that contribute to greenhouse gas (GHG) emissions but are not considered in IEO2016 could have significant effects on national or regional shares of total global GHG emissions and the achievement of INDCs. EIA's projections for CO2 emissions may change significantly as laws and policies aimed at reducing GHG emissions are implemented and enforced, or if existing laws are enhanced.

## Policies to limit CO2 emissions in the United States and China

The United States and China are the countries with the most energy-related CO2 emissions. Together they accounted for about 40% of global CO2 emissions in 2012. In 2014, both countries announced their Intended Nationally Determined Contributions (INDCs) to the mitigation of their respective GHG emissions. It remains unclear, however, whether either country will meet or exceed its announced target. Further efforts to reduce GHG emissions were discussed at the Conference of the Parties to the United Nations Framework on Climate Change (COP21), held in Paris November 30 through December 12, 2015.[332] EIA will continue to assess the targets resulting from COP21 for inclusion in future analyses.

The United States, which in 2009 set a goal of reducing GHG emissions by 17% from 2005 levels by 2020, has now announced an INDC of 26% to 28% below its 2005 level by 2025. China's INDC states the objective of peaking its CO2 emissions by about 2030 while making best efforts to achieve an earlier peak. China's INDC also proposes a goal of 20% nonfossil energy use in 2030. In addition, in September 2015, China announced its intent to expand the country's seven current regional emissions trading programs in to a national cap-and-trade program beginning in 2017, although specific emissions caps and other policy details have not yet been announced. China surpassed the United States as the world's largest CO2 emitter in 2008 (Figure 9-2). In 2012 its CO2 emissions per capita were about one-third of the U.S. level, and its emissions per unit of economic output were about 70% higher than the U.S. level.

**Figure 9-2. Carbon dioxide emissions from energy consumption in the United States and China, 1990–2012**




In the United States, about 80% of all CO2 emissions in 2012 were related to energy, with the remainder attributed to sources such as cement production, agricultural activities, land use changes, and forestry. Two of the largest sources of U.S. energy-related CO2 emissions are the transportation sector and the electric power sector. For transportation, the main mechanism to reduce emissions is increasing the stringency of fuel economy and GHG emissions standards for both light-duty vehicles and heavy trucks. For electric power, the U.S. Environmental Protection Agency (EPA) has finalized a Clean Power Plan (CPP) aimed at significantly reducing CO2 emissions from existing fossil-fueled generators.

In China, the ultimate achievement of emissions targets will depend on its need to balance environmental goals with economic growth and development. In the past, China's energy demand growth has been driven by development plans as part of the government's five-year planning cycles that have centered mainly on industrial expansion. China is still industrializing, and its energy needs will grow despite slowing economic growth and a shift to less energy-intensive industries. China's energy mix is dominated by coal, the most carbon-intensive fossil fuel, and it is likely to remain so for the foreseeable future. If its total CO2 emissions are to peak near 2030, coal consumption will have to stop growing, and perhaps decline substantially, between 2015 and 2035 unless carbon capture and storage (CCS) technology, which is a relatively new technology, is rapidly adopted.

*(continued on page 141)*

[332]United Nations Framework Convention on Climate Change, "United Nations Climate Change Conference, Paris, France," http://unfccc.int/files/meetings/paris_nov_2015/application/pdf/overview-schedule_cop21cmp11.pdf.

China's growing middle class is expected to increase its demand for energy services as income per capita increases, and its sectoral shares of energy consumption are expected to continue shifting from industry to the building and transportation sectors. In both sectors, the energy efficiencies of China's technologies have improved in recent years, which should help China curb the rate of growth in its energy use.

## CO2 emissions by fuel

Energy-related CO2 emissions from the use of liquid fuels, natural gas, and coal all increase in the IEO2016 Reference case, with the relative contributions of the individual fuels shifting over time (Figure 9-3). In 1990, CO2 emissions associated with the consumption of liquid fuels accounted for the largest portion (43%) of global emissions. In 2012, they had fallen to 36% of total emissions, and they remain at that level through 2040 in the IEO2016 Reference case. Coal, which is the most carbon-intensive fossil fuel, became the leading source of world energy-related CO2 emissions in 2006, and it remains the leading source through 2040 in the Reference case. However, although coal accounted for 39% of total emissions in 1990 and 43% in 2012, its share is projected to decline to 38% in 2040, only slightly higher than the liquid fuels share. The natural gas share of CO2 emissions, which was relatively small at 19% of total GHG emissions in 1990 and 20% in 2012, increases in the IEO2016 Reference case to 26% of total fossil fuel emissions in 2040.

Worldwide consumption of energy derived from fossil fuels grows by about 177 quadrillion Btu from 2012 to 2040 in the IEO2016 Reference case. In 2012, fossil fuels accounted for 84% of worldwide energy consumption. If fossil fuels had kept the same share in the Reference case, they would have increased from 461 quadrillion Btu in 2012 to 684 quadrillion Btu by 2040. However, with the increase in renewable and nuclear energy, the share of fossil fuels in total decreases to 78%, and the mix of those fossil fuels changes. The coal share of total energy use falls from 28% in 2012 to 22% in 2040. Over the same period, the liquids share falls from 33% to 30%, while the natural gas share rises from 23% to 26%.

The net result of both the reduced share of fossil-fuel energy and the shift in the fossil-fuel mix is that projected energy-related CO2 emissions in 2040 are 10% lower in 2040 than they would have been without the changes. Natural gas is the largest contributor to CO2 emissions growth in both the OECD and non-OECD economies, accounting for 100% and 35%, respectively, of the projected CO2 emissions increases in the two regions (Figure 9-4).

Growth in CO2 emissions from the consumption of liquids worldwide is projected to average 1.0% annually in the IEO2016 Reference case, resulting in an absolute increase of 3.8 billion metric tons of liquids-related CO2 emissions from 2012 to 2040. In the OECD countries, liquids-related CO2 emissions decline by an average of 0.1%/year. In the non-OECD countries, rising demand for transportation and industrial uses of liquid fuels contributes to a growth rate of 1.9%/year for total CO2 emissions from the combustion of liquid fuels.

In the IEO2016 Reference case, world coal-related CO2 emissions show slower growth over the 28-year projection period than in projections in past IEOs, averaging 0.6%/year and resulting in an 18% increase in coal-related emissions and a 14% increase if the U.S. CPP is included. Coal-related emissions in the OECD and non-OECD regions increase by 0.1% and 0.8%/year from 2012 to 2040, respectively. Under the U.S. CPP, OECD coal-related CO2 emissions would decrease by 0.4%/year. The world's top three national sources of coal-related emissions are China, India, and the United States, which remain at the top throughout the projection period and in combination account for 70% of world coal-related CO2 emissions in 2040.

**Figure 9-3. World energy-related carbon dioxide emissions by fuel type, 1990–2040 (billion metric tons)**

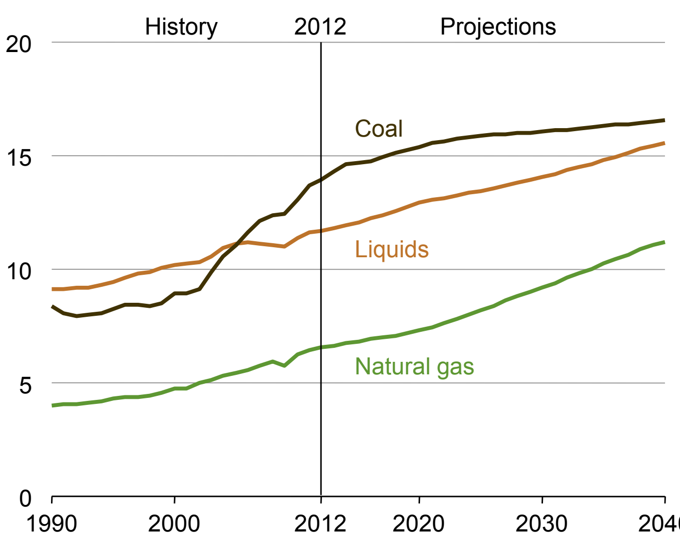
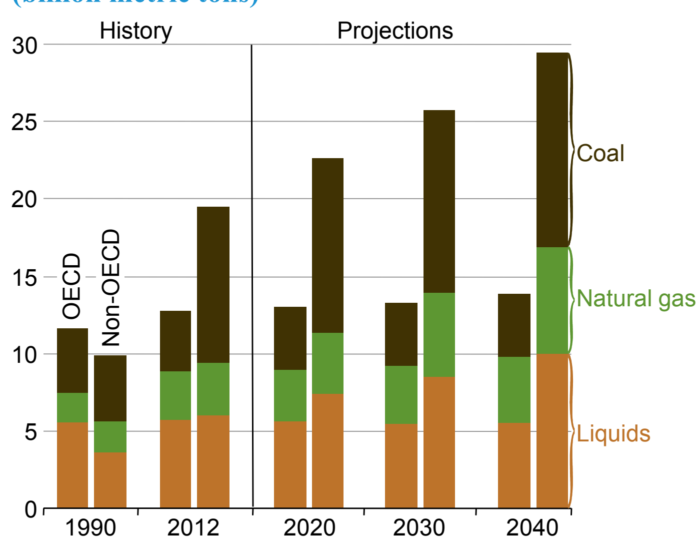



**Figure 9-4. OECD and non-OECD energy-related carbon dioxide emissions by fuel type, 1990–2040 (billion metric tons)**



## Uncertainties in projecting European Union emissions reductions

The European Union (EU) has pledged a goal of a 40% reduction in total GHG emissions from 1990 levels by 2030.[333] However, at this time only parts of the programs to implement the pledge are in place, and for the IEO2016 Reference case EIA has not assumed anything beyond what EU countries now have in place. Considering programs currently in place, OECD Europe's energy-related carbon dioxide emissions rise slightly through 2040; however, Turkey and Norway (which are included in OECD Europe) are not part of the EU.[334]

Much of the difference between the emissions level projected in the Reference case and the EU goal would likely be covered by emission allowance credits. The cornerstone of the EU's efforts to reduce GHG emissions is the EU Emissions Trading System (ETS). The EU ETS is a cap-and-trade system that covers approximately 45% of the GHG emissions in the EU's 28 member states, plus Iceland, Liechtenstein, and Norway. The ETS was introduced in 2005 in a first-phase trial period that lasted through 2007. The second phase began in 2008 and ended in 2012. A large surplus of allowances that were accumulated during the first two phases will be available for use in the third phase, from 2013 to 2020.[335]The ETS credit surplus is one of many uncertainties surrounding the prospects for EU reductions. Other uncertainties include:

- Negotiations under way to reform the post-2020 ETS are expected to continue for another two years.[336] Without a better understanding of the rules after 2020, it is difficult to project emissions to 2040.
- With economic growth in the EU lower than projected when the ETS was designed, there are substantial banked (unused) credits. Also, covered industries continue to receive some free allowances. The surplus credits are estimated to reach 2.6 billion metric tons in 2020 with nearly 2.0 billion metric tons remaining in 2030 unless the post-2020 reforms are stringent and enforceable.[337] Further, the current reduction factor of 1.74% (the rate at which the annual cap is reduced) probably is inadequate to achieve the stated EU goals.[338]
- In terms of energy-related carbon dioxide emissions, renewable electricity generation is the primary marginal source of noncarbon energy. In the IEO2016 Reference case, OECD Europe's renewable energy goals are evaluated on a country-by-country basis.
- Nuclear power, the largest existing source of noncarbon energy, faces an uncertain future in OECD Europe. For example, France has been phasing in renewables to replace nuclear capacity. In addition, several EU nations, including Germany and Switzerland, have announced plans to phase out or shut down their operating nuclear reactors in the aftermath of the March 2011 disaster at Japan's Fukushima Daiichi nuclear power plant.
- On the energy-demand side, OECD Europe already has achieved relatively low energy intensity, and the region's energy intensity is projected to fall from 4.4 thousand Btu per dollar of GDP in 2012 (measured in purchasing power parity terms) to 3.2 thousand Btu per dollar in 2040 in the IEO2016 Reference case.
- The price of EU ETS credits has remained around 8 Euros over the past few years, well below the level of 40 to 50 Euros that many analysts believe would be required to initiate a larger shift from fossil fuels to noncarbon energy sources.[339]
- Another important uncertainty is whether land use, land use change, and forestry (LULUCF) will be included in the EU goal. As of April 2016, specific rules for their inclusion had not been published[340] and LULUCF is not included in the IEO2016 projections. However, the rules could greatly influence levels of energy-related carbon dioxide emissions.

[333]European Commission, "Climate Action: 2030 climate & energy framework" (September 24, 2015), http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm.

[334]The EU membership intersects with the countries included in the IEO2016 OECD Europe region, as follows: Norway and Turkey are included in OECD Europe but are not EU member countries; Bulgaria, Cyprus, Latvia, Lithuania, Malta, and Romania are EU member countries but are not included in OECD Europe; Israel is reported in OECD Europe for statistical purposes.

[335]Carbon Market Watch, "Policy Briefing: What's needed to fix the EU's carbon market: Recommendations for the Market Stability Reserve and future ETS reform proposals" (July 9, 2014), http://carbonmarketwatch.org/whats-needed-to-fix-the-eus-carbon-market-recommendations-for-the-market-stability-reserve-and-future-ets-reform-proposals/.

[336]Bloomberg New Energy Finance, "EU Carbon Allowances Rise as More Bidders Participate in Sales" (September 8, 2015), www.bnef.com (subscription site).

[337]Carbon Market Watch, "Policy Briefing: What's needed to fix the EU's carbon market: Recommendations for the Market Stability Reserve and future ETS reform proposals" (July 9, 2014), http://carbonmarketwatch.org/whats-needed-to-fix-the-eus-carbon-market-recommendations-for-the-market-stability-reserve-and-future-ets-reform-proposals/.

[338]Carbon Market Watch, "Policy Briefing: What's needed to fix the EU's carbon market: Recommendations for the Market Stability Reserve and future ETS reform proposals" (July 9, 2014), http://carbonmarketwatch.org/whats-needed-to-fix-the-eus-carbon-market-recommendations-for-the-market-stability-reserve-and-future-ets-reform-proposals/.

[339]businessGreen, "EU carbon price tops €8 for first time since 2012" (July 21, 2015), http://www.businessgreen.com/bg/news/2418553/eu-carbon-price-tops-eur8-for-first-time-since-2012 (subscription site).

[340]Climate Action Tracker, "European Union" (April 7, 2016), http://climateactiontracker.org/countries/eu.html.

## CO2 emissions by region

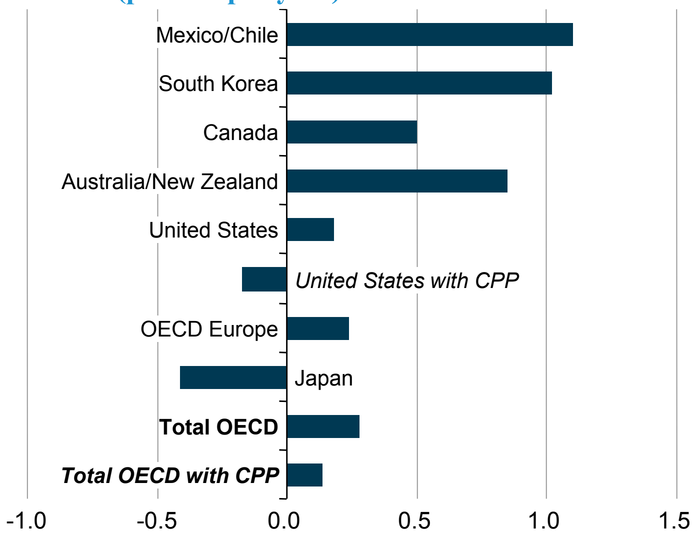
World energy-related CO2 emissions increase at an average annual rate of 1.0% from 2012 to 2040 in the IEO2016 Reference case (Table 9-2). On average, OECD emissions increase by 0.3%/year and non-OECD emissions increase by 1.5%/year. Among the OECD countries, energy-related CO2 emissions from the combined region of Mexico and Chile grow by an average of 1.1%/year, and emissions from South Korea increase by an average of 1.0%/year (Figure 9-6). The two regions also have among the highest projected rates of economic growth in the OECD over the period, with Mexico/Chile's GDP increasing by 3.1%/year in the IEO2016 Reference case and South Korea's GDP increasing by 2.1%/year. For all the other OECD countries and regions, CO2 emissions increase by an average of less than 1%/year. Japan's CO2 emissions decline by an average of 0.4%/year from 2012 to 2040. In OECD Europe, CO2 emissions increase by 0.2%/year; and in the OECD Americas, CO2 emissions increase by 0.3%/year over the projection period, with the growth rate dropping to 0%/year after implementation of the CPP. In 2040, OECD Europe accounts for about 10% of world emissions, as compared with about 13% in 2012, and the OECD Americas region accounts for 16% (or 15%, if the CPP is taken into account), down from 20% in 2012. For the OECD region as a whole, GDP growth averages 2.0%/year.

Non-OECD Asia accounts for about 59% of the growth in world CO2 emissions from 2012 to 2040. China's emissions grow by an average of only 1.0%/year (Figure 9-7), but they still account for 41% of the total increase in non-OECD Asia's emissions.

**Table 9-2. World energy-related carbon dioxide emissions by region and country in the Reference case with and without the U.S. Clean Power Plan (CPP), 1990–2040 (billion metric tons)**

| Region/Country | 1990 | 2012 | 2020 | 2030 | 2040 | Average annual percent change, 1990–2012 | Average annual percent change, 2012–40 | Total change, 2012–40 (billion metric tons) | Percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|---|
| **OECD** | **11.6** | **12.8** | **13.0** | **13.3** | **13.8** | **0.4** | **0.3** | **1.0** | **8.0** |
| **OECD with CPP** | **11.6** | **12.8** | **12.7** | **12.7** | **13.3** | **0.4** | **0.1** | **0.5** | **3.9** |
| OECD Americas | 5.8 | 6.3 | 6.6 | 6.7 | 6.9 | 0.3 | 0.3 | 0.5 | 8.6 |
| OECD Americas with CPP | 5.8 | 6.3 | 6.3 | 6.1 | 6.4 | 0.3 | 0.0 | 1.0 | 0.3 |
| United States | 5.0 | 5.3 | 5.5 | 5.5 | 5.5 | 0.1 | 0.2 | 0.4 | 6.9 |
| United States with CPP | 5.0 | 5.3 | 5.2 | 4.9 | 5.0 | 0.1 | -0.2 | -0.2 | -4.6 |
| Canada | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.9 | 0.5 | 0.1 | 14.9 |
| Mexico/Chile | 0.3 | 0.5 | 0.5 | 0.6 | 0.7 | 1.9 | 1.1 | 0.2 | 35.7 |
| OECD Europe | 4.2 | 4.1 | 4.1 | 4.3 | 4.4 | -0.1 | 0.2 | 0.3 | 7.1 |
| OECD Asia | 1.6 | 2.3 | 2.4 | 2.4 | 2.5 | 1.8 | 0.3 | 0.2 | 8.2 |
| Japan | 1.0 | 1.2 | 1.2 | 1.2 | 1.1 | 0.8 | -0.4 | -0.1 | -10.9 |
| South Korea | 0.2 | 0.6 | 0.7 | 0.8 | 0.8 | 4.5 | 1.0 | 0.2 | 32.9 |
| Australia/ New Zealand | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 1.8 | 0.8 | 0.1 | 26.7 |
| **Non-OECD** | **9.9** | **19.5** | **22.6** | **25.8** | **29.4** | **3.1** | **1.5** | **9.9** | **50.9** |
| Non-OECD Europe and Eurasia | 4.2 | 2.9 | 2.9 | 3.1 | 3.2 | -1.6 | 0.3 | 0.2 | 7.9 |
| Russia | 2.4 | 1.8 | 1.8 | 1.9 | 1.9 | -1.3 | 0.1 | 0.1 | 3.8 |
| Other | 1.8 | 1.1 | 1.1 | 1.2 | 1.3 | -2.1 | 0.5 | 0.2 | 14.3 |
| Non-OECD Asia | 3.7 | 12.2 | 14.5 | 16.4 | 18.7 | 5.6 | 1.5 | 6.5 | 53.2 |
| China | 2.3 | 8.4 | 9.9 | 10.6 | 11.1 | 6.1 | 1.0 | 2.7 | 31.9 |
| India | 0.6 | 1.8 | 2.1 | 2.7 | 3.7 | 5.3 | 2.7 | 2.0 | 109.9 |
| Other | 0.8 | 2.0 | 2.5 | 3.1 | 3.9 | 4.3 | 2.3 | 1.9 | 91.2 |
| Middle East | 0.7 | 1.9 | 2.4 | 2.9 | 3.4 | 4.8 | 2.2 | 1.6 | 82.0 |
| Africa | 0.7 | 1.2 | 1.4 | 1.8 | 2.2 | 2.7 | 2.3 | 1.1 | 89.2 |
| Non-OECD Americas | 0.7 | 1.3 | 1.4 | 1.6 | 1.9 | 3.0 | 1.4 | 0.6 | 46.8 |
| Brazil | 0.2 | 0.5 | 0.5 | 0.7 | 0.8 | 3.5 | 1.5 | 0.3 | 52.4 |
| Other | 0.4 | 0.8 | 0.8 | 1.0 | 1.1 | 2.7 | 1.3 | 0.3 | 43.1 |
| **Total World** | **21.4** | **32.3** | **35.6** | **39.1** | **43.2** | **1.9** | **1.0** | **10.9** | **33.9** |
| **Total World with CPP** | **21.4** | **32.3** | **35.3** | **38.5** | **42.7** | **1.9** | **1.0** | **10.4** | **32.3** |

**Figure 9-5. Average annual growth of energy-related carbon dioxide emissions in OECD economies with and without the U.S. Clean Power Plan (CPP), 2012–40 (percent per year)**




India's $CO_2$ emissions increase by 2.7%/year, and emissions in the rest of non-OECD Asia increase by an average of 2.3%/year, accounting for 30% and 29%, respectively, of the total non-OECD Asia increase in $CO_2$ emissions. From 2012 to 2040, emissions from coal combustion in non-OECD Asia increase by 2.2 billion metric tons, and emissions from liquid fuels increase by 2.3 billion metric tons, while emissions from natural gas combustion increase by 2.0 billion metric tons (Figure 9-7).

Among the non-OECD regions, the slowest growth in $CO_2$ emissions, at 0.3%/year, is projected for non-OECD Europe and Eurasia in the IEO2016 Reference case. Total $CO_2$ emissions in non-OECD Europe and Eurasia increase only slightly, from 2.9 billion metric tons in 2012 to 3.2 billion metric tons in 2040, in part because of Russia's projected population decline and increasing reliance on nuclear power to meet electricity demand in the future. Natural gas continues to be the region's leading source of energy-related $CO_2$ emissions throughout the projection, accounting for 69% of regional energy-related $CO_2$ emissions growth from 2012 to 2040.

**Figure 9-6. Average annual growth of energy-related carbon dioxide emissions in non-OECD economies, 2012–40 (percent per year)**

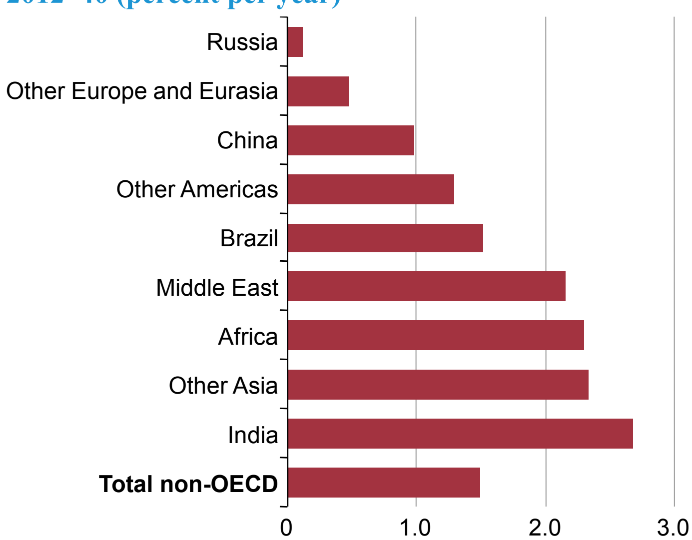
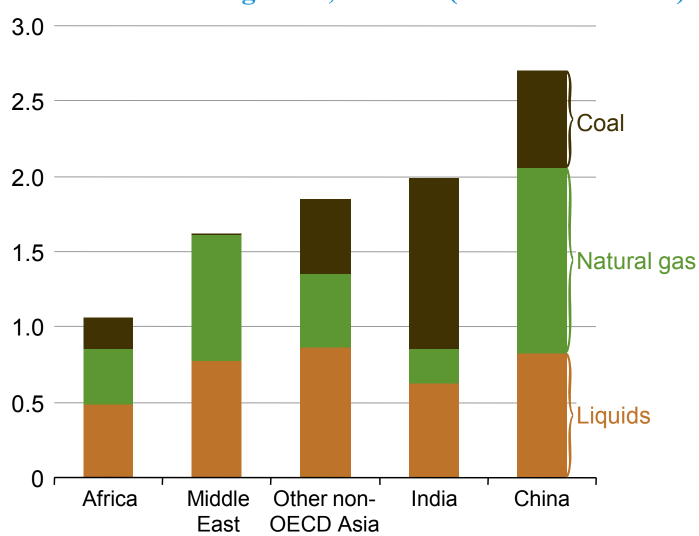



**Figure 9-7. Increases in carbon dioxide emissions by fuel type in non-OECD regions with the highest absolute emissions growth, 2012–40 (billion metric tons)**




## U.S. Clean Power Plan Rule

In March 2015, the United States submitted its Intended Nationally Determined Contribution (INDC) for GHG emissions reduction to the United Nations Framework Convention on Climate Change (UNFCCC). The U.S. INDC pledges an emissions reduction of 26% to 28% below 2005 levels by 2025.[341] The U.S. Environmental Protection Agency (EPA) published the final version of the U.S. Clean Power Plan rule (CPP) in August 2015.[342] The effect of that rule was not included in the baseline for U.S. projections in IEO2016 because of the timing of its release. However, estimates of the effect based on the proposed rule have been included in this chapter.

*(continued on page 145)*

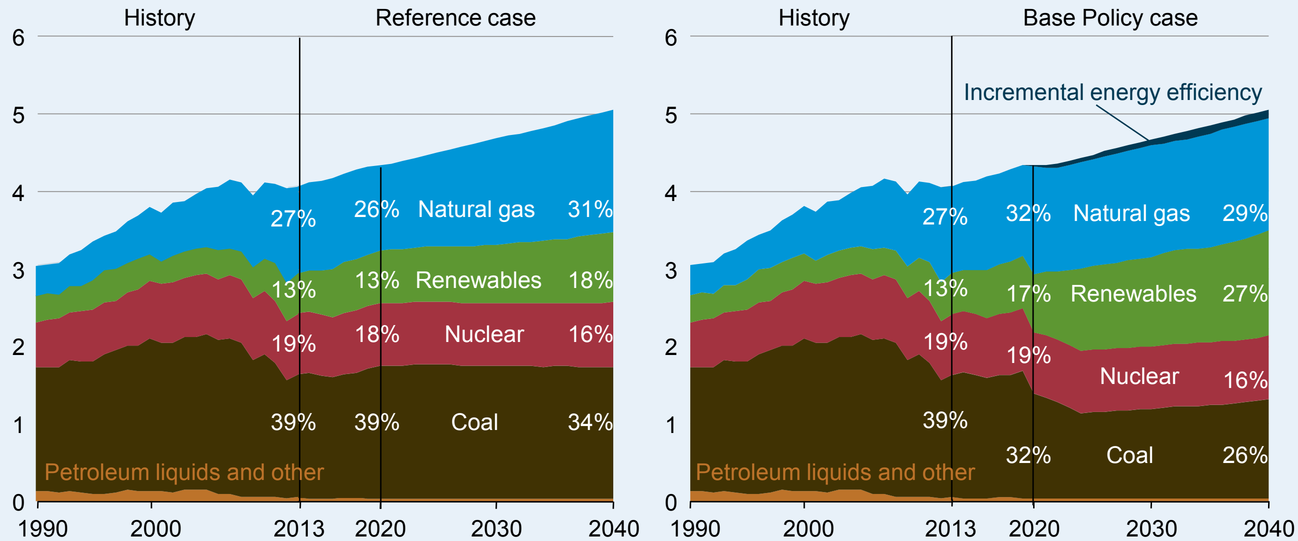
[341] The White House, Office of the Press Secretary, "FACT SHEET: U.S. Reports its 2025 Emissions Target to the UNFCCC" (Washington, DC: March 31, 2015), https://www.whitehouse.gov/the-press-office/2015/03/31/fact-sheet-us-reports-its-2025-emissions-target-unfccc.

[342] United States Environmental Protection Agency, "Clean Power Plan for Existing Power Plants" (Washington, DC: November 16, 2015), http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants.

The final CPP reflects substantive changes from the proposed rule, but the overall expected level of $CO_2$ emissions reduction is similar to the level expected under the proposed rule. To the extent that the requirements are similar, a reasonable indicator of potential changes resulting from the final CPP is provided in EIA's analysis of the proposed rule.[343]

In EIA's analysis, the key impact of the proposed CPP rule was a projected reduction in U.S. coal-fired generation, by 560 billion kilowatthours (kWh) in 2030, to approximately 33% less than the projected 1,713 billion kWh without the CPP rule (Figure 9-8). Thus, under the proposed rule, the projected reduction in output from U.S. coal-fired power plants would yield $CO_2$ emissions of roughly 613 million metric tons (25% below 2005 levels) in 2020 and roughly 830 million metric tons (34% below 2005 levels) in 2030.

**Figure 9-8. U.S. electricity generation by primary fuel in the AEO2015 Reference case, 1990–2040, and incremental energy savings in the AEO2015 Base Policy case, 1990–2040 (trillion kilowatthours)**




The Clean Power Plan leads to a decrease in coal-fired generation, reflecting both additional coal plant retirements and lower utilization rates for plants that remain in use. In the early stages of implementation, natural gas-fired generation is the primary replacement for coal, followed by a shift to renewables in the mid-2020s. The actual mix of additional renewables and gas-fired generation resulting from the Clean Power Plan will depend on CPP implementation decisions made by states, the availability of tax credits for renewables—which were extended by legislation enacted in December 2015, and fuel and technology costs.

Changes to the final CPP, made by the EPA rule in response to comments, relate to the structure and implementation of the CPP program rather than to its requirements. Significant changes from the proposed rule to the final rule include:

- More gradual implementation over the compliance period
- Increased emphasis on trading options, including examples of rules for rate-based and mass-based programs to speed the creation of interstate cooperative programs
- Reduced variability across states in the required $CO_2$ emissions reductions, with the EPA basing its emission rate standards on $CO_2$ averages determined at the electricity grid interconnection level rather than at the state level.

## IEO2016 factors influencing trends in energy-related CO2 emissions

Many factors influence a country's level of $CO_2$ emissions. Two key measures provide useful insights for the analysis of trends in energy-related emissions:

- The *carbon intensity of energy consumption* is a measure of the amount of $CO_2$ associated with each unit of energy used. It directly links changes in $CO_2$ emissions levels with changes in energy usage. Carbon emissions vary by energy source, with coal being the most carbon-intensive major fuel, followed by oil and natural gas. Nuclear power and some renewable energy sources (i.e., solar and wind) do not directly generate $CO_2$ emissions. Consequently, changes in the fuel mix alter overall carbon intensity. Over time, declining carbon intensity can offset increasing energy consumption to some extent. If energy consumption increased and carbon intensity decreased by a proportional factor, energy-related $CO_2$ emissions would remain constant. A decline in carbon intensity can indicate a shift away from fossil fuels, a shift towards less carbon-intensive fossil fuels, or both.

[343] U.S. Energy Information Administration, "Analysis of the Impacts of the Clean Power Plan" (Washington, DC: May 22, 2015), http://www.eia.gov/analysis/requests/powerplants/cleanplan/.

- The *energy intensity of economic activity* is a measure of energy consumption per unit of economic activity, as measured by GDP. It relates changes in energy consumption to changes in economic output. Increased energy use and economic growth generally occur together, although the degree to which they are linked varies across regions, stages of economic development, and the mix of products produced.

As with carbon intensity, regional energy intensities do not necessarily remain constant over time. Energy intensity can be indicative of the energy efficiency of an economy's capital stock (vehicles, appliances, manufacturing equipment, power plants, etc.). For example, if an old power plant is replaced with a more thermally efficient unit, it is possible to meet the same level of electricity demand with a lower level of primary energy consumption, thereby decreasing energy intensity.

Energy intensity is acutely affected by structural changes within an economy—in particular, the relative shares of its output sectors (manufacturing versus service, for example). Higher concentrations of energy-intensive industries, such as oil and natural gas extraction, will yield higher overall energy intensities, whereas countries with proportionately larger service sectors will tend to have lower energy intensities.

Carbon intensity multiplied by energy intensity provides a measure of CO2 emissions per dollar of GDP (CO2/GDP)—that is, the carbon intensity of economic output. Carbon intensity of output is another common measure used in analysis of changes in CO2 emissions, and it is sometimes used as a standalone measure. However, when the goal is to determine the relative strengths of forces driving changes in carbon intensity, disaggregation of the components helps to determine whether a change in carbon intensity is the result of a change in the country's fuel mix or a change in the relative energy intensity of its economic activity.

## The Kaya decomposition of emissions trends

The Kaya Identity provides an intuitive approach to the interpretation of historical trends and future projections of energy-related CO2 emissions.[344] It can be used to decompose total CO2 emissions as the product of individual factors that explicitly link energy-related CO2 emissions to energy consumption, the level of economic output as measured by gross domestic product (GDP), and population size.

The Kaya Identity expresses total CO2 emissions as the product of (1) carbon intensity of energy consumption (CO2/E), (2) energy intensity of economic activity (E/GDP), (3) economic output per capita (GDP/POP), and (4) population (POP):

$$CO2 = (CO2 / E) \times (E / GDP) \times (GDP / POP) \times POP$$

Using 2012 data as an example, world energy-related CO2 emissions totaled 32.2 billion metric tons in that year, world energy consumption totaled 549 quadrillion Btu, world GDP totaled $94.46 trillion, and the total world population was 7.073 billion. Using those figures in the Kaya equation yields the following: 58.6 metric tons CO2 per billion Btu of energy *(CO2/E),* 5.8 thousand Btu of energy per dollar of GDP *(E/GDP),* and $13,355 output per capita *(GDP/POP).* Appendix J shows calculations of the Kaya factors for all IEO2016 regions over the projection period.

Of the four Kaya components, policymakers generally focus on the energy intensity of economic output *(E/GDP)* and CO2 intensity of the energy supply *(CO2/E).* Reducing growth in per-capita output may have a mitigating influence on emissions, but governments generally pursue policies to increase rather than reduce output per capita to advance economic objectives.

Policies related to energy intensity of GDP typically involve improvements to energy efficiency. However, the measure is also sensitive to shifts in the energy-intensive portion of a country's trade balance, and improvements may simply reflect a greater reliance on imports of manufactured goods. If the country producing the imported goods is less energy efficient, a greater reliance on imported goods could lead to a worldwide increase in energy consumption and related CO2 emissions. Policies related to the CO2 intensity of energy supply typically focus on promotion of low-carbon or zero-carbon sources of energy.

With all of the components of the Kaya identity having small annual percentage rates of change, the percentage rate of change in CO2 emission levels over time approximates the sum of the component percentage rate of change. Table 9-3 shows the average rates of change in total CO2 emissions and each individual Kaya component from 2012 to 2040 in the IEO2016 Reference case. The most significant driver of growth in energy-related CO2 emissions is economic output per capita. The average annual growth rate of output per capita for non-OECD countries (3.2% from 2012 to 2040) in particular dominates all other Kaya components in the 28-year projection. For OECD countries, on the other hand, the 1.6% average annual increase in output per capita is nearly offset by the 1.4% annual decline in energy intensity.

Except for Japan and Russia—where population is expected to decline from 2012 to 2040—population growth is also a contributing factor to emissions increases, along with output per capita. The Kaya identity separates population *(POP)* growth from output per capita *(GDP/POP)* so that the influence of the two components of total GDP growth can be measured. As indicated in Table 9-3, in all regions population growth is less than the growth of output per capita. For non-OECD countries, increases in output per capita coupled with population growth overwhelm improvements in energy intensity and carbon intensity. Although the same was true for the OECD countries from 1990 to 2012, the projection horizon shows OECD growth in output per capita and population largely balanced by reductions in energy intensity and carbon intensity (Figure 9-9, Figure 9-10, and Figure 9-11).

[344]See Intergovernmental Panel on Climate Change, "Emissions Scenarios," http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=50.

Over the 2012–40 projection period, the energy intensity of economic output declines in all IEO2016 regions. The trend is particularly pronounced in the non-OECD countries, where energy intensity of output decreases by an average of 2.2%/year, compared with a decrease of 1.4%/year in the OECD countries. Worldwide, the most significant decline in the energy intensity of output is projected for China, at 2.8%/year. However, that decline is offset by a projected increase in China's output per capita, averaging 4.6%/year over the same period.

Carbon intensity of energy supply is projected to decline in all IEO2016 regions from 2012 to 2040, but to a lesser extent than energy intensity. The combined decrease in carbon intensity for the non-OECD countries is slightly larger than the combined decrease for the OECD countries—0.5%/year versus 0.3%/year. With the effects of the U.S. CPP included, the rate of decline in carbon intensity for the OECD countries is 0.4%/year. China's projected decrease in energy intensity is the largest, averaging 0.8%/year. In most regions, decreases in the energy consumption shares for liquid fuels and coal (the most carbon-intensive fuels), combined with increases in the shares for renewable energy, nuclear power, and natural gas, reduce the global carbon intensity of energy supply.

**Table 9-3. Average annual changes in Kaya factors by region and country in the Reference case with and without the U.S. Clean Power Plan (CPP), 2012–40 (percent per year)**

| Region/Country | Carbon intensity of energy supply (CO2/E) | Energy intensity of economic activity (E/GDP) | Output per capita (GDP/POP) | Population (POP) | Carbon dioxide emissions |
|---|---|---|---|---|---|
| OECD | **-0.3** | **-1.4** | **1.6** | **0.4** | **0.3** |
| OECD with CPP | **-0.4** | **-1.4** | **1.6** | **0.4** | **0.2** |
| OECD Americas | -0.3 | -1.9 | 1.7 | 0.7 | 0.3 |
| OECD Americas with CPP | -0.5 | -1.9 | 1.7 | 0.7 | 0.1 |
| United States | -0.2 | -2.0 | 1.7 | 0.7 | 0.2 |
| United States with CPPs | -0.5 | -2.0 | 1.7 | 0.7 | -0.1 |
| Canada | -0.3 | -1.3 | 1.2 | 0.8 | 0.5 |
| Mexico/Chile | -0.5 | -1.4 | 2.3 | 0.8 | 1.1 |
| OECD Europe | -0.3 | -1.1 | 1.5 | 0.2 | 0.2 |
| OECD Asia | -0.5 | -0.5 | 1.3 | 0.0 | 0.3 |
| Japan | -0.5 | -0.5 | 1.0 | -0.4 | -0.4 |
| South Korea | -0.4 | -0.6 | 1.8 | 0.2 | 1.0 |
| Australia/New Zealand | -0.6 | -1.1 | 1.2 | 1.3 | 0.8 |
| Non-OECD | **-0.5** | **-2.2** | **3.2** | **1.0** | **1.5** |
| Non-OECD Europe and Eurasia | -0.2 | -2.2 | 2.9 | -0.1 | 0.3 |
| Russia | -0.1 | -1.7 | 2.4 | -0.4 | 0.1 |
| Other | -0.3 | -2.8 | 3.6 | 0.1 | 0.5 |
| Non-OECD Asia | -0.6 | -2.4 | 4.1 | 0.6 | 1.5 |
| China | -0.8 | -2.8 | 4.6 | 0.1 | 1.0 |
| India | -0.5 | -2.3 | 4.7 | 0.8 | 2.7 |
| Other | -0.2 | -1.5 | 3.1 | 1.0 | 2.3 |
| Middle East | -0.2 | -1.3 | 2.0 | 1.7 | 2.2 |
| Africa | -0.3 | -2.2 | 2.7 | 2.1 | 2.3 |
| Non-OECD Americas | -0.1 | -1.1 | 1.7 | 0.9 | 1.4 |
| Brazil | -0.2 | -0.7 | 1.9 | 0.5 | 1.5 |
| Other | **-0.1** | **-1.4** | **1.7** | **1.1** | **1.3** |
| Total World | **-0.4** | **-1.9** | **2.4** | **0.9** | **1.0** |
| Total World with CPP | **-0.4** | **-1.9** | **2.4** | **0.9** | **1.0** |

**Figure 9-9. OECD and non-OECD carbon intensity of energy supply, 1990–2040 (metric tons carbon per billion Btu)**

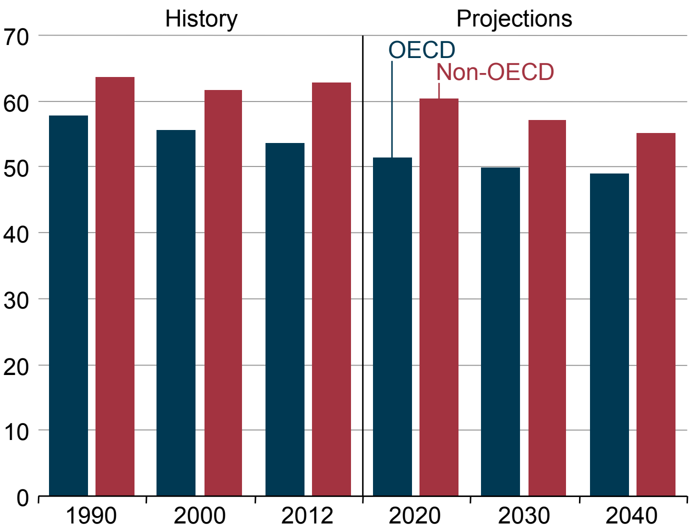



**Figure 9-10. OECD and non-OECD energy intensity, 1990–2040 (thousand Btu per 2010 dollar of GDP)**

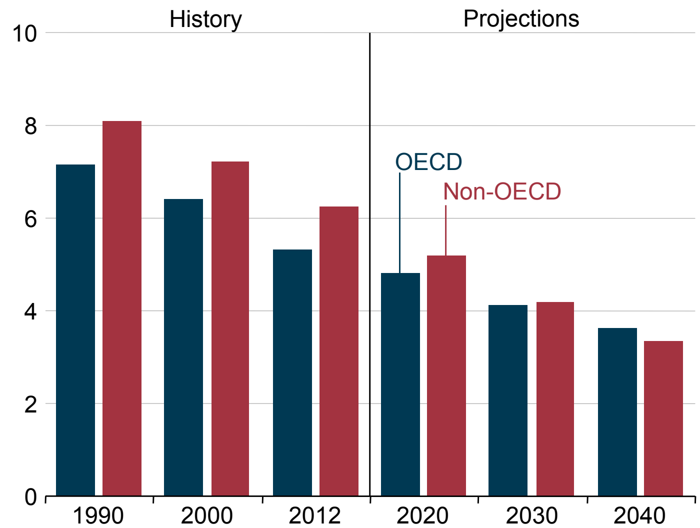
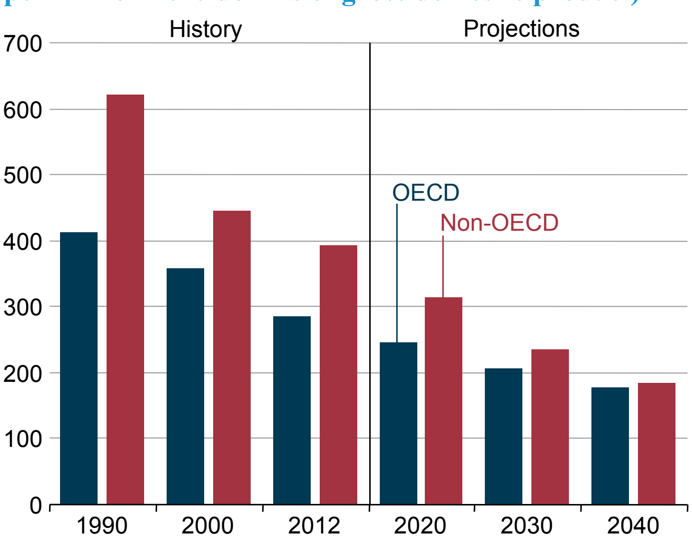



**Figure 9-11. OECD and non-OECD carbon intensity of economic output, 1990–2040 (metric tons carbon per million 2010 dollars of gross domestic product)**



# Data sources

**Links current as of March 2016**

## Executive summary

**Figure ES-1. World energy consumption by country grouping, 2012–40:** *2012:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure ES-2. Total world energy consumption by energy source, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008; and *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), www.eia.gov/analysis/requests/powerplants/cleanplan/.

**Figure ES-3. Petroleum and other liquid fuels production by region and type in the Reference case, 2000–2040:** *History:* U.S. Energy Information Administration (EIA), Office of Petroleum, Natural Gas, and Biofuels Analysis. ***Projections:*** EIA, Generate World Oil Balance application (2016)

**Figure ES-4. World increase in natural gas production, 2012–40:** *2012:* U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, International Natural Gas Model (2016).

**Figure ES-5. Coal consumption in China, India, and the United States, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure ES-6. World net electricity generation by energy source, 2012–40:** *History:* Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure ES-7. World transportation sector delivered energy consumption by energy source, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure ES-8. World energy-related carbon dioxide emissions by fuel type, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Chapter 1. World energy demand and economic outlook

**Table 1-1. World energy consumption by country grouping, 2012–40:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-1. World energy consumption, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-2. World energy consumption by region, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-3. World total gross domestic product, 1990–2040:** Oxford Economics Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and U.S. Energy Information Administration, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC, April 2015), AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

**Figure 1-4. Non-OECD energy consumption by region, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-5. World energy consumption by energy source, 1990–2040:** *History:* U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008; *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC, April 2015), AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), www.eia.gov/analysis/requests/powerplants/cleanplan/.

**Figure 1-6. World net electricity generation by energy source, 2012–40:** *History:* Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-7. World net electricity generation from renewable energy sources, 2012 and 2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 1-8. World nuclear electricity generation capacity by region, 2012 and 2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table 1-2. World gross domestic product by country grouping, 2012–40:** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and U.S. Energy Information Administration, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC, April 2015), AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

**Figure 1-9. OECD real gross domestic product growth rates, 2012–40:** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and U.S. Energy Information Administration, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC, April 2015), AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

**Figure 1-10. Non-OECD real gross domestic product growth rates, 2012–40:** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site).

**Figure 1-11. World energy consumption by region in three economic growth cases, 2012, 2025, and 2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (WEPS+2016), runs IEO2016-reference_final_2016.02.19_115008, IEO2016-macro_high_2016.02.19_115030, and macro_low_2016.02.19_115022.

**Figure 1-12. World energy consumption by fuel in three oil price cases, 2012 and 2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (WEPS+2016), runs IEO2016-reference_final_2016.02.19_115008, IEO2016-oil_price_high_2016.02.19_115017, and IEO2016-oil_price_low_2016.02.19_115103.

## Chapter 2. Petroleum and other liquid fuels

**Figure 2-1. North Sea Brent crude oil spot prices in three cases, 1990–2040:** U.S. Energy Information Administration (EIA), Short-Term Energy Outlook (March 2016) and EIA, *Annual Energy Outlook 2015,* DOE-EIA-0383(2015) (Washington, DC: April 2015).

**Table 2-1. North Sea Brent crude oil spot prices in three cases, 2012–40:** U.S. Energy Information Administration, *Annual Energy Outlook 2015,* DOE-EIA-0383(2015) (Washington, DC: April 2015).

**Figure 2-2. World tight oil production in the IEO2016 Reference case, 2012, 2020, and 2040:** *2012:* U.S. Energy Information Administration (EIA), Office of Petroleum, Natural Gas, and Biofuels Analysis. ***Projections:*** EIA, Generate World Oil Balance application (2016).

**Figure 2-3. EIA/ARI assessments of shale gas and tight oil resources in Argentina's Nequen Basin and China's Sichuan Basin:** U.S. Energy Information Administration and Advanced Resources International, Inc., *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Washington, DC: June 2013), http://www.eia.gov/analysis/studies/worldshalegas/archive/2013/pdf/fullreport_2013.pdf.

**Figure 2-4. Liquid fuels supply and demand (million barrels per day) and North Sea Brent crude oil equilibrium prices (2013 dollars per barrel) in three cases, 2040:** Representation estimated by U.S. Energy Information Administration, Office of Energy Markets and Financial Analysis, Macroeconomic Analysis Team.

**Figure 2-5. World consumption of residual fuel oil, 1986-2012:** U.S. Energy Information Administration, International Energy Statistics database (as of October 2015), www.eia.gov/ies.

**Figure 2-6. Current and proposed Marpol regulations on sulfur content of residual fuel oil, 2000–2027:** U.S. Energy Information Administration, Office of Petroleum, Natural Gas, and Biofuels Analysis based on International Maritime Organization, "International Convention for the Prevention of Pollution from Ships (MARPOL)" (2015), http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.

**Figure 2-7. OECD and non-OECD petroleum and other liquid fuels consumption, IEO2016 Reference case, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table 2-2. World petroleum and other liquid fuels consumption by region, IEO2016 Reference case, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 2-8. Non-OECD petroleum and other liquid fuels consumption by region, IEO2016 Reference case, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 2-9. Energy consumption in U.S. and China refineries by fuel type, 2012:** ***United States:*** U.S. Energy Information Administration, Petroleum Supply Monthly (Washington, DC: September 2015). ***IEA China Estimate:*** International Energy Agency (IEA), Energy Balances of Non-OECD Countries (Paris, France: 2015), www.iea.org (subscription site).

**Figure 2-10. Petroleum and other liquid fuels production by region and type in the IEO2016 Reference case, 2000–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, Generate World Oil Balance application (2016).

**Figure 2-11. OPEC crude and lease condensate production by region in the IEO2016 Reference case, 2012, 2020, and 2040:** ***2012:*** U.S. Energy Information Administration (EIA), Office of Energy Analysis, Office of Petroleum, Natural Gas & Biofuels Analysis. ***2020 and 2040:*** EIA, Generate World Oil Balance application (2016).

**Figure 2-12. World other liquid fuels production by source, 2012, 2020, and 2040:** ***2012:*** U.S. Energy Information Administration (EIA), Office of Energy Analysis, Office of Petroleum, Natural Gas & Biofuels Analysis. ***2020 and 2040:*** EIA, Generate World Oil Balance application (2016).

**Figure 2-13. Crude oil production in Algeria, 2005-14:** U.S. Energy Information Administration, International Energy Statistics Database (as of August 2015), www.eia.gov/ies.

**Figure 2-14. Natural gas production in Algeria, 2005-14:** U.S. Energy Information Administration, International Energy Statistics Database (as of March 2016), www.eia.gov/ies.

**Figure 2-15. Oil and natural gas basins and pipeline infrastructure in Algeria:** U.S. Energy Information Administration, IHS EDIN, and Advanced Resources International.

**Table 2-3. Pemex bid Round One process and timeline as of December 2015:** IHS Energy, "Mexico: Lessons learned from early auctions drive new approaches for deepwater," *Oil and Gas Risk Service* (November 20, 2015), https://connect.ihs.com/Document/Show/gi/2852236?connectPath=Search (subscription site); and C. Pascual, IHS Energy, "Mexico's energy reforms: strategic challenges ahead," *CERA Special Report* (August 2015), https://connect.ihs.com/Document/Show/gi/2823645?connectPath=Search (subscription site).

**Figure 2-16. World production of renewable diesel fuels from hydroprocessed esters and fatty acids, 2011–14:** U.S. Energy Information Administration, based on F.O. Licht (April 2015), https://www.agra-net.com/agra/world-ethanol-and-biofuels-report/ (subscription site).

**Figure 2-17. World petroleum and other liquid fuels consumption in three cases, 2012 and 2040:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***2040:*** EIA, World Energy Projection System Plus (WEPS+2016), runs IEO2016-reference_final_2016.02.19_115008, IEO2016-oil_price_high_2016.02.19_115017, and IEO2016-oil_price_low_2016.02.19_115103.

**Figure 2-18. World petroleum and other liquid fuels production in three cases, 2012 and 2040:** ***2012:*** U.S. Energy Information Administration (EIA), Office of Energy Analysis, Office of Petroleum, Natural Gas & Biofuels Analysis. ***2040:*** EIA, EIA, Generate World Oil Balance application (2016).

## Chapter 3. Natural gas

**Figure 3-1. World natural gas consumption, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-2. World increase in natural gas production by country grouping, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***2040:*** EIA, International Natural Gas Model (2016).

**Figure 3-3. Natural gas production by type in China, Canada, and the United States, 2012 and 2040:** U.S. Energy Information Administration, International Natural Gas Model (2016).

**Figure 3-4. OECD Americas natural gas consumption by country, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-5. OECD Americas change in natural gas consumption by country and end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-6. OECD Europe natural gas consumption by end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-7. OECD Asia natural gas consumption by country and end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-8. World crude oil, natural gas, and liquefied natural gas prices, 2010–2015:** ***U.S. Henry Hub spot market prices:*** U.S. Energy Information Administration. ***Japan customs-cleared crude oil prices:*** Petroleum Association of Japan, http://www.paj.gr.jp/english/; ***Japan LNG:*** Ministry of Finance Japan, http://www.mof.go.jp/english/. ***Brent crude oil spot market prices:*** Bloomberg LP.

**Figure 3-9. Asia Pacific natural gas trade by country and contract type, 2010 and 2014:** International Group of Liquefied Natural Gas Importers (GIIGNL), *The LNG Industry 2010,* http://www.giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_the_lng_industry_2010.pdf, and *The LNG Industry 2014,* http://www.giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_2015_annual_report.pdf.

**Figure 3-10. Non-OECD Europe and Eurasia natural gas consumption, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-11. Non-OECD Asia natural gas consumption by region, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-12. Middle East natural gas consumption by end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-13. Africa natural gas consumption by end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 3-14. Non-OECD Americas natural gas consumption by end-use sector, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table 3-1. World natural gas production by region and country in the Reference case, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, International Natural Gas Model (2016) and EIA, *Annual Energy Outlook 2015,* DOE-EIA-0383(2015) (Washington, DC: April 2015).

**Figure 3-15. OECD natural gas production by country and region, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, International Natural Gas Model (2016) and EIA, *Annual Energy Outlook 2015,* DOE-EIA-0383(2015) (Washington, DC: April 2015).

**Figure 3-16. OECD Europe natural gas production, 2012–40:** U.S. Energy Information Administration, International Natural Gas Model (2016).

**Figure 3-17. Middle East natural gas production by country, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, International Natural Gas Model (2016).

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## Chapter 7. Industrial sector energy consumption

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**Figure 7-1. Global gross output by industrial subsectors, 2012 and 2040:** ***United States:*** U.S. Energy Information Administration, *Annual Energy Outlook 2015,* DOE/EIA-0383 (Washington, DC: April 2015). ***Rest of World:*** Oxford Economics, Global Economic Model (September 2015), www.oxfordeconomics.com (subscription site).

**Figure 7-2. OECD industrial sector delivered energy consumption by energy source, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-3. Non-OECD industrial sector delivered energy consumption by energy source, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-4. Energy-intensive industry shares of total OECD industrial sector energy consumption, 2012 and 2040:** ***2012:*** Oxford Economics, Global Industrial Model (June 2015), www.oxfordeconomics.com (subscription site).

**Figure 7-5. Energy-intensive industry shares of total non-OECD industrial sector energy consumption, 2012 and 2040:** Oxford Economics, Global Industrial Model (June 2015), www.oxfordeconomics.com (subscription site).

**Figure 7-6. OECD Europe industrial sector delivered energy consumption by energy source, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-7. Steel and aluminum production from primary and secondary sources in China and the United States, 2012:** U.S. Geological Survey, Minerals Information, "Recycling Statistics and Information," (September 9, 2015), http://minerals.usgs.gov/minerals/pubs/commodity/recycle/, and Bureau of International Recycling, "Ferrous Metals," (undated), http://www.bir.org/industry/ferrous-metals/.

**Figure 7-8. Coal and electricity consumption in China's steel industry, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-9. Industrial energy consumption and urban population growth in China, 1990–2012:** National Bureau of Statistic of China, *China Statistical Yearbook* (various issues), http://www.stats.gov.cn/tjsj/ndsj/2014/indexee.htm.

**Figure 7-10. Comparisons of energy use per capita and per dollar of gross domestic product in China and the OECD, 1990–2012:** U.S. Energy Information Administration, International Energy Statistics Database (as of May 2015), www.eia.gov/ies, and Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site).

**Figure 7-11. Fuel and feedstock consumption in China's bulk chemicals industry, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-12. Non-OECD Asia (excluding China and India) industrial sector delivered energy consumption by energy source, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 7-13. Electricity shares of industrial sector energy demand in China, the Philippines and the OECD, 1975–2012:** International Monetary Fund, World Economic Outlook Database (October 2015), https://www.imf.org/external/pubs/ft/weo/2015/02/weodata/index.aspx.

**Figure 7-14. Industrial sector electricity demand in China by industry type, 1971–2012:** International Monetary Fund, World Economic Outlook Database (October 2015), https://www.imf.org/external/pubs/ft/weo/2015/02/weodata/index.aspx.

**Figure 7-15. Industrial sector electricity demand in the Philippines by industry type, 1971–2012:** International Monetary Fund, World Economic Outlook Database (October 2015), https://www.imf.org/external/pubs/ft/weo/2015/02/weodata/index.aspx.

## Chapter 8. Transportation sector energy consumption

**Figure 8-1. Delivered transportation energy consumption by country grouping, 2012–40:** ***2012:*** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics Database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-2. World transportation sector delivered energy consumption by energy source, 2010–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-3. Annual average growth in delivered transportation energy consumption by OECD region, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-4. Average annual growth in delivered transportation energy consumption by non-OECD region, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-5. World transportation sector delivered energy consumption by passenger modes, 2012 and 2040:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-6. World transportation sector delivered energy consumption by freight modes, 2012 and 2040:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-7. Change in OECD and non-OECD delivered transportation energy consumption by passenger mode, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-8. World transportation energy consumption by mode, 2012:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-9. Transportation energy consumption by mode in selected countries and regions, 2012:** ***United States:*** U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015), www.eia.gov/aeo. ***All other countries:*** EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-10. World passenger jet aircraft stocks by region and type, 2013:** Jet Information Services, Inc., World Jet Inventory 2013, https://www.jetinventory.com (subscription site).

**Figure 8-11. Gross domestic product (thousand 2010 dollars per person) and aircraft stock per capita (aircraft per million people) by region, 2013:** Jet Information Services, Inc., World Jet Inventory 2013, https://www.jetinventory.com (subscription site).

**Figure 8-12. Change in OECD and non-OECD delivered transportation energy consumption by freight mode, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-13. GDP per capita in selected regions and countries, 2012–40:** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site).

**Figure 8-14. Passenger travel per capita in selected regions and countries, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-15. Light-duty vehicles per thousand people in selected regions and countries, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-16. OECD and non-OECD passenger travel by selected travel modes, 2012–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-17. World air passenger travel by region, 2013:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-18. World domestic and international air passenger travel by region, 2013:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-19. OECD and non-OECD gross domestic product per capita (thousand 2010 dollars) and air passenger travel per capita (revenue passenger-miles) by region, 2013:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-20. OECD and non-OECD industrial gross output per capita, excluding service industries, 2012–40:** ***2012:*** Oxford Economics, Global Industrial Model and Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site). ***Projections:*** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 8-21. OECD and non-OECD freight movement per capita by truck, rail, and domestic marine vessels, 2010–40:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Chapter 9. Energy-related CO2 emissions

**Table 9-1. World energy-related carbon dioxide emissions by fuel type, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008 and EIA, *Analysis of the Impacts of the Clean Power Plan,* CPP Base Policy case (May 2015), http://www.eia.gov/analysis/requests/powerplants/cleanplan/pdf/powerplant.pdf.

**Figure 9-1. OECD and non-OECD energy-related carbon dioxide emissions, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-2. Carbon dioxide emissions from energy consumption in the United States and China, 1990–2012:** ***History:*** *Population and GDP:* Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site). *Carbon dioxide emissions:* U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-3. World energy-related carbon dioxide emissions by fuel type, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-4. OECD and non-OECD energy-related carbon dioxide emissions by fuel type, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table 9-2. World energy-related carbon dioxide emissions by region and country in the Reference case with and without the U.S. Clean Power Plan (CPP), 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008 and EIA, *Analysis of the Impacts of the Clean Power Plan,* CPP Base Policy case (May 2015), http://www.eia.gov/analysis/requests/powerplants/cleanplan/pdf/powerplant.pdf.

**Figure 9-5. Average annual growth of energy-related carbon dioxide emissions in OECD economies, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***2040:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-6. Average annual growth of energy-related carbon dioxide emissions in non-OECD economies, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***2040:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-7. Increases in carbon dioxide emissions by fuel type in non-OECD regions with the highest absolute emissions growth, 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***2040:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-8. U.S. electricity generation by primary fuel in the AEO2015 Reference case, 1990–2040, and incremental energy savings in the AEO2015 Base Policy case, 1990–2040:** U.S. Energy Information Administration, *Analysis of the Impacts of the Clean Power Plan* (Washington, DC: May 2015), p. 23, https://www.eia.gov/analysis/requests/powerplants/cleanplan/pdf/powerplant.pdf.

**Table 9-3. Average annual changes in Kaya factors by region and country in the Reference case with and without the U.S. Clean Power Plan (CPP), 2012–40:** ***2012:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections: United States:*** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383 (Washington, DC: April 2015), www.eia.gov/aeo, and EIA, *Analysis of the Impacts of the Clean Power Plan,* CPP Base Policy case (May 2015), http://www.eia.gov/analysis/requests/powerplants/cleanplan/pdf/powerplant.pdf. ***Rest of world:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-9. OECD and non-OECD carbon intensity of energy supply, 1990–2040:** ***History:*** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-10. OECD and non-OECD energy intensity, 1990–2040:** ***History:*** *energy consumption:* U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***GDP:*** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site). ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Figure 9-11. OECD and non-OECD carbon intensity of economic output, 1990–2040:** ***History:*** *energy consumption:* U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. ***GDP:*** Oxford Economics, Global Economic Model (June 2015), www.oxfordeconomics.com (subscription site). ***Projections:*** EIA, World Energy Projections System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

Appendix A

# Reference case projections

## Table A1. World total primary energy consumption by region, Reference case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **120.6** | **118.1** | **125.7** | **128.1** | **130.7** | **133.8** | **138.1** | **0.6** |
| United States[a] | 96.8 | 94.4 | 100.8 | 102.0 | 102.9 | 103.8 | 105.7 | 0.4 |
| Canada | 14.5 | 14.5 | 15.1 | 15.6 | 16.3 | 17.1 | 18.1 | 0.8 |
| Mexico and Chile | 9.3 | 9.2 | 9.8 | 10.5 | 11.6 | 12.8 | 14.3 | 1.6 |
| **OECD Europe** | **82.0** | **81.4** | **84.9** | **87.5** | **90.3** | **93.1** | **95.5** | **0.6** |
| **OECD Asia** | **39.4** | **39.0** | **43.4** | **45.0** | **46.2** | **47.4** | **48.5** | **0.8** |
| Japan | 21.2 | 20.8 | 21.9 | 22.3 | 22.3 | 22.2 | 21.5 | 0.1 |
| South Korea | 11.3 | 11.4 | 13.9 | 14.7 | 15.4 | 16.1 | 16.9 | 1.4 |
| Australia and New Zealand | 6.9 | 6.8 | 7.6 | 8.1 | 8.5 | 9.2 | 10.1 | 1.4 |
| **Total OECD** | **242.0** | **238.4** | **253.9** | **260.6** | **267.2** | **274.3** | **282.1** | **0.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **49.9** | **50.7** | **51.8** | **54.8** | **56.4** | **57.9** | **57.6** | **0.5** |
| Russia | 30.9 | 32.1 | 33.2 | 34.7 | 35.1 | 35.5 | 34.5 | 0.3 |
| Other | 19.0 | 18.6 | 18.7 | 20.1 | 21.3 | 22.4 | 23.1 | 0.8 |
| **Non-OECD Asia** | **168.2** | **175.9** | **222.7** | **246.4** | **269.9** | **295.1** | **322.1** | **2.2** |
| China | 109.4 | 115.0 | 147.3 | 159.4 | 170.4 | 180.7 | 190.1 | 1.8 |
| India | 25.0 | 26.2 | 32.8 | 38.4 | 44.9 | 52.8 | 62.3 | 3.2 |
| Other | 33.7 | 34.7 | 42.7 | 48.6 | 54.6 | 61.6 | 69.6 | 2.5 |
| **Middle East** | **29.9** | **31.7** | **40.8** | **45.4** | **50.7** | **56.6** | **61.8** | **2.4** |
| **Africa** | **20.1** | **21.5** | **26.1** | **30.0** | **33.8** | **38.4** | **44.0** | **2.6** |
| **Non-OECD Americas** | **30.5** | **31.0** | **33.5** | **36.7** | **39.7** | **43.3** | **47.3** | **1.5** |
| Brazil | 14.8 | 15.2 | 16.3 | 18.1 | 20.0 | 22.0 | 24.3 | 1.7 |
| Other | 15.7 | 15.8 | 17.2 | 18.6 | 19.8 | 21.2 | 23.0 | 1.4 |
| **Total Non-OECD** | **298.6** | **310.8** | **375.0** | **413.3** | **450.5** | **491.2** | **532.8** | **1.9** |
| **Total World** | **540.5** | **549.3** | **628.9** | **673.9** | **717.7** | **765.6** | **815.0** | **1.4** |

[a]Includes the 50 States and the District of Columbia.
Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A2. World total energy consumption by region and fuel, Reference case, 2011–40
(quadrillion Btu)

| | History | | Projections | | | | | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | |
| OECD | | | | | | | | |
| OECD Americas | | | | | | | | |
| Liquids | 45.3 | 44.6 | 46.4 | 46.1 | 46.0 | 46.2 | 46.7 | 0.2 |
| Natural gas | 31.8 | 32.8 | 33.9 | 35.5 | 37.7 | 39.5 | 41.4 | 0.8 |
| Coal | 21.0 | 18.7 | 20.3 | 20.5 | 20.1 | 20.0 | 20.0 | 0.2 |
| Nuclear | 9.4 | 9.2 | 9.5 | 9.4 | 9.5 | 9.5 | 9.7 | 0.2 |
| Other | 13.1 | 12.9 | 15.6 | 16.6 | 17.5 | 18.6 | 20.3 | 1.6 |
| **Total** | **120.6** | **118.1** | **125.7** | **128.1** | **130.7** | **133.8** | **138.1** | **0.6** |
| OECD Europe | | | | | | | | |
| Liquids | 30.4 | 29.6 | 28.3 | 28.0 | 28.2 | 28.5 | 28.8 | -0.1 |
| Natural gas | 19.2 | 18.3 | 19.7 | 21.1 | 23.0 | 24.3 | 26.1 | 1.3 |
| Coal | 12.9 | 13.4 | 13.2 | 13.3 | 13.1 | 12.8 | 12.6 | -0.2 |
| Nuclear | 8.8 | 8.6 | 7.9 | 8.3 | 8.8 | 9.0 | 8.5 | 0.0 |
| Other | 10.7 | 11.5 | 15.7 | 16.7 | 17.3 | 18.5 | 19.6 | 1.9 |
| **Total** | **82.0** | **81.4** | **84.9** | **87.5** | **90.3** | **93.1** | **95.5** | **0.6** |
| OECD Asia | | | | | | | | |
| Liquids | 16.0 | 16.8 | 15.7 | 15.4 | 15.3 | 15.3 | 15.3 | -0.3 |
| Natural gas | 8.2 | 8.4 | 9.5 | 10.5 | 11.1 | 12.1 | 13.0 | 1.6 |
| Coal | 9.7 | 9.7 | 10.2 | 10.1 | 10.1 | 10.1 | 10.1 | 0.1 |
| Nuclear | 3.0 | 1.6 | 3.9 | 4.5 | 4.7 | 4.6 | 4.4 | 3.7 |
| Other | 2.5 | 2.5 | 4.1 | 4.6 | 5.1 | 5.4 | 5.7 | 3.0 |
| **Total** | **39.4** | **39.0** | **43.4** | **45.0** | **46.2** | **47.4** | **48.5** | **0.8** |
| Total OECD | | | | | | | | |
| Liquids | 91.7 | 90.9 | 90.4 | 89.5 | 89.5 | 90.0 | 90.8 | 0.0 |
| Natural gas | 59.2 | 59.5 | 63.1 | 67.1 | 71.7 | 75.9 | 80.5 | 1.1 |
| Coal | 43.6 | 41.8 | 43.7 | 44.0 | 43.3 | 42.9 | 42.7 | 0.1 |
| Nuclear | 21.2 | 19.3 | 21.3 | 22.1 | 23.0 | 23.1 | 22.5 | 0.6 |
| Other | 26.3 | 27.0 | 35.5 | 37.9 | 39.8 | 42.5 | 45.5 | 1.9 |
| **Total** | **242.0** | **238.4** | **253.9** | **260.6** | **267.2** | **274.3** | **282.1** | **0.6** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | | | | | | | | |
| Liquids | 10.8 | 10.7 | 12.0 | 12.7 | 12.7 | 12.8 | 12.6 | 0.6 |
| Natural gas | 23.4 | 23.7 | 23.1 | 24.5 | 25.7 | 26.7 | 26.7 | 0.4 |
| Coal | 9.6 | 10.2 | 9.4 | 9.4 | 9.6 | 9.8 | 9.6 | -0.2 |
| Nuclear | 3.0 | 3.1 | 3.9 | 4.3 | 4.3 | 4.3 | 4.3 | 1.2 |
| Other | 3.0 | 3.0 | 3.4 | 3.8 | 4.0 | 4.3 | 4.4 | 1.4 |
| **Total** | **49.9** | **50.7** | **51.8** | **54.8** | **56.4** | **57.9** | **57.6** | **0.5** |
| Non-OECD Asia | | | | | | | | |
| Liquids | 42.1 | 44.3 | 55.8 | 61.4 | 67.2 | 73.8 | 81.2 | 2.2 |
| Natural gas | 15.0 | 15.5 | 21.5 | 28.1 | 35.2 | 44.0 | 52.5 | 4.4 |
| Coal | 93.3 | 95.5 | 109.2 | 112.9 | 114.4 | 116.6 | 119.5 | 0.8 |
| Nuclear | 1.6 | 1.7 | 4.8 | 6.9 | 10.9 | 13.5 | 16.2 | 8.3 |
| Other | 16.1 | 18.8 | 31.5 | 37.1 | 42.1 | 47.2 | 52.6 | 3.7 |
| **Total** | **168.2** | **175.9** | **222.7** | **246.4** | **269.9** | **295.1** | **322.1** | **2.2** |

See notes at end of table.

*(continued on page 165)*

**Table A2. World total energy consumption by region and fuel, Reference case, 2011–40 (continued)**
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Non-OECD (continued)** | | | | | | | | |
| Middle East | | | | | | | | |
| Liquids | 15.1 | 16.0 | 20.9 | 21.7 | 23.3 | 25.3 | 27.1 | 1.9 |
| Natural gas | 14.5 | 15.4 | 18.6 | 21.5 | 24.7 | 27.4 | 30.3 | 2.5 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 3.2 |
| Nuclear | 0.0 | 0.0 | 0.4 | 0.6 | 1.0 | 1.3 | 1.6 | 18.4 |
| Other | 0.2 | 0.2 | 0.8 | 1.4 | 1.6 | 2.3 | 2.6 | 9.0 |
| **Total** | **29.9** | **31.7** | **40.8** | **45.4** | **50.7** | **56.6** | **61.8** | **2.4** |
| Africa | | | | | | | | |
| Liquids | 7.0 | 7.4 | 9.5 | 10.6 | 11.6 | 12.8 | 14.6 | 2.5 |
| Natural gas | 4.1 | 4.7 | 5.8 | 6.6 | 8.1 | 9.9 | 11.7 | 3.3 |
| Coal | 4.6 | 4.8 | 5.4 | 5.8 | 6.0 | 6.4 | 7.0 | 1.4 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 4.4 |
| Other | 4.3 | 4.5 | 5.4 | 6.8 | 7.8 | 9.0 | 10.3 | 3.0 |
| **Total** | **20.1** | **21.5** | **26.1** | **30.0** | **33.8** | **38.4** | **44.0** | **2.6** |
| Non-OECD Americas | | | | | | | | |
| Liquids | 13.6 | 14.2 | 15.6 | 16.6 | 17.5 | 18.5 | 19.8 | 1.2 |
| Natural gas | 5.4 | 5.4 | 6.2 | 7.0 | 7.8 | 8.6 | 9.6 | 2.0 |
| Coal | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.1 | 1.1 | 1.0 |
| Nuclear | 0.2 | 0.2 | 0.4 | 0.4 | 0.8 | 0.8 | 0.9 | 5.1 |
| Other | 10.4 | 10.3 | 10.5 | 11.9 | 12.8 | 14.3 | 15.9 | 1.6 |
| **Total** | **30.5** | **31.0** | **33.5** | **36.7** | **39.7** | **43.3** | **47.3** | **1.5** |
| Total Non-OECD | | | | | | | | |
| Liquids | 88.6 | 92.6 | 113.8 | 123.0 | 132.3 | 143.3 | 155.3 | 1.9 |
| Natural gas | 62.4 | 64.8 | 75.2 | 87.8 | 101.4 | 116.6 | 130.9 | 2.5 |
| Coal | 108.4 | 111.5 | 124.9 | 129.2 | 131.2 | 134.0 | 137.5 | 0.8 |
| Nuclear | 5.0 | 5.2 | 9.6 | 12.4 | 17.2 | 20.3 | 23.4 | 5.5 |
| Other | 34.1 | 36.8 | 51.5 | 60.9 | 68.3 | 77.0 | 85.8 | 3.1 |
| **Total** | **298.6** | **310.8** | **375.0** | **413.3** | **450.5** | **491.2** | **532.8** | **1.9** |
| Total World | | | | | | | | |
| Liquids | 180.3 | 183.6 | 204.2 | 212.5 | 221.8 | 233.2 | 246.0 | 1.1 |
| Natural gas | 121.6 | 124.2 | 138.3 | 154.8 | 173.1 | 192.5 | 211.4 | 1.9 |
| Coal | 152.0 | 153.3 | 168.6 | 173.2 | 174.4 | 176.9 | 180.2 | 0.6 |
| Nuclear | 26.2 | 24.5 | 30.9 | 34.6 | 40.2 | 43.4 | 46.0 | 2.3 |
| Other | 60.4 | 63.8 | 87.0 | 98.8 | 108.1 | 119.5 | 131.4 | 2.6 |
| **Total** | **540.5** | **549.3** | **628.9** | **673.9** | **717.7** | **765.6** | **815.0** | **1.4** |

Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table A3. World gross domestic product (GDP) by region expressed in purchasing power parity, Reference case, 2011–40**
(billion 2010 dollars)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **18,616** | **19,080** | **23,390** | **26,577** | **29,942** | **33,569** | **37,770** | **2.5** |
| United States[a] | 15,021 | 15,369 | 18,801 | 21,295 | 23,894 | 26,659 | 29,898 | 2.4 |
| Canada | 1,396 | 1,422 | 1,700 | 1,881 | 2,074 | 2,293 | 2,529 | 2.1 |
| Mexico and Chile | 2,200 | 2,288 | 2,890 | 3,400 | 3,974 | 4,618 | 5,343 | 3.1 |
| **OECD Europe** | **18,670** | **18,638** | **21,496** | **23,621** | **25,697** | **27,809** | **30,074** | **1.7** |
| **OECD Asia** | **6,904** | **7,051** | **8,034** | **8,575** | **9,091** | **9,647** | **10,198** | **1.3** |
| Japan | 4,299 | 4,373 | 4,695 | 4,886 | 5,025 | 5,141 | 5,173 | 0.6 |
| South Korea | 1,528 | 1,563 | 1,960 | 2,135 | 2,327 | 2,535 | 2,764 | 2.1 |
| Australia and New Zealand | 1,077 | 1,115 | 1,379 | 1,554 | 1,739 | 1,971 | 2,262 | 2.6 |
| **Total OECD** | **44,189** | **44,769** | **52,921** | **58,772** | **64,731** | **71,026** | **78,042** | **2.0** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5,380** | **5,535** | **6,614** | **7,764** | **9,009** | **10,437** | **11,870** | **2.8** |
| Russia | 3,165 | 3,273 | 3,645 | 4,109 | 4,604 | 5,171 | 5,623 | 2.0 |
| Other | 2,215 | 2,262 | 2,969 | 3,655 | 4,405 | 5,266 | 6,247 | 3.7 |
| **Non-OECD Asia** | **26,261** | **27,914** | **44,139** | **56,222** | **69,542** | **84,680** | **102,015** | **4.7** |
| China | 13,286 | 14,309 | 23,154 | 29,515 | 36,303 | 43,694 | 51,749 | 4.7 |
| India | 5,706 | 5,957 | 10,165 | 13,423 | 17,126 | 21,541 | 26,863 | 5.5 |
| Other | 7,268 | 7,648 | 10,819 | 13,284 | 16,112 | 19,445 | 23,403 | 4.1 |
| **Middle East** | **4,986** | **5,072** | **6,951** | **8,578** | **10,309** | **12,164** | **14,144** | **3.7** |
| **Africa** | **4,355** | **4,561** | **6,539** | **8,295** | **10,559** | **13,467** | **17,144** | **4.8** |
| **Non-OECD Americas** | **6,427** | **6,604** | **7,952** | **9,259** | **10,561** | **11,985** | **13,615** | **2.6** |
| Brazil | 2,916 | 2,968 | 3,410 | 3,949 | 4,494 | 5,077 | 5,728 | 2.4 |
| Other | 3,510 | 3,636 | 4,542 | 5,310 | 6,067 | 6,908 | 7,887 | 2.8 |
| **Total Non-OECD** | **47,408** | **49,686** | **72,195** | **90,118** | **109,979** | **132,734** | **158,789** | **4.2** |
| **Total World** | **91,598** | **94,455** | **125,115** | **148,891** | **174,711** | **203,760** | **236,831** | **3.3** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

**Table A4. World gross domestic product (GDP) by region expressed in market exchange rates, Reference case, 2011–40**
(billion 2010 dollars)

| Region | History 2011 | History 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **18,006** | **18,440** | **22,566** | **25,585** | **28,757** | **32,166** | **36,120** | **2.4** |
| United States[a] | 15,021 | 15,369 | 18,801 | 21,295 | 23,894 | 26,659 | 29,898 | 2.4 |
| Canada | 1,662 | 1,694 | 2,024 | 2,240 | 2,470 | 2,730 | 3,012 | 2.1 |
| Mexico and Chile | 1,324 | 1,377 | 1,741 | 2,049 | 2,392 | 2,777 | 3,210 | 3.1 |
| **OECD Europe** | **18,874** | **18,833** | **21,535** | **23,540** | **25,466** | **27,401** | **29,488** | **1.6** |
| **OECD Asia** | **8,038** | **8,209** | **9,263** | **9,868** | **10,434** | **11,044** | **11,642** | **1.3** |
| Japan | 5,479 | 5,574 | 5,984 | 6,227 | 6,404 | 6,552 | 6,593 | 0.6 |
| South Korea | 1,134 | 1,160 | 1,455 | 1,585 | 1,728 | 1,882 | 2,052 | 2.1 |
| Australia and New Zealand | 1,425 | 1,475 | 1,824 | 2,056 | 2,302 | 2,610 | 2,957 | 2.6 |
| **Total OECD** | **44,918** | **45,483** | **53,365** | **58,993** | **64,657** | **70,611** | **77,249** | **1.9** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **2,581** | **2,654** | **3,138** | **3,669** | **4,239** | **4,891** | **5,533** | **2.7** |
| Russia | 1,590 | 1,645 | 1,832 | 2,065 | 2,313 | 2,599 | 2,826 | 2.0 |
| Other | 990 | 1,010 | 1,307 | 1,604 | 1,925 | 2,292 | 2,707 | 3.6 |
| **Non-OECD Asia** | **11,517** | **12,271** | **19,246** | **24,402** | **30,021** | **36,334** | **43,472** | **4.6** |
| China | 6,615 | 7,124 | 11,528 | 14,695 | 18,075 | 21,755 | 25,765 | 4.7 |
| India | 1,728 | 1,804 | 3,077 | 4,063 | 5,184 | 6,520 | 8,131 | 5.5 |
| Other | 3,174 | 3,343 | 4,641 | 5,645 | 6,762 | 8,060 | 9,576 | 3.8 |
| **Middle East** | **2,353** | **2,454** | **3,271** | **3,993** | **4,765** | **5,591** | **6,454** | **3.5** |
| **Africa** | **1,909** | **2,004** | **2,840** | **3,576** | **4,514** | **5,706** | **7,203** | **4.7** |
| **Non-OECD Americas** | **4,079** | **4,160** | **4,935** | **5,729** | **6,523** | **7,389** | **8,368** | **2.5** |
| Brazil | 2,295 | 2,335 | 2,683 | 3,108 | 3,536 | 3,995 | 4,507 | 2.4 |
| Other | 1,784 | 1,825 | 2,252 | 2,622 | 2,987 | 3,393 | 3,861 | 2.7 |
| **Total Non-OECD** | **22,438** | **23,544** | **33,431** | **41,370** | **50,061** | **59,911** | **71,031** | **4.0** |
| **Total World** | **67,356** | **69,027** | **86,796** | **100,362** | **114,718** | **130,522** | **148,280** | **2.8** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

## Table A5. World liquids consumption by region, Reference case, 2011–40
(million barrels per day)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **23.6** | **23.2** | **24.4** | **24.4** | **24.3** | **24.4** | **24.6** | **0.2** |
| United States[a] | 18.9 | 18.5 | 19.6 | 19.6 | 19.4 | 19.3 | 19.3 | 0.2 |
| Canada | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 0.2 |
| Mexico and Chile | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.7 | 2.9 | 0.6 |
| **OECD Europe** | **14.5** | **14.1** | **13.7** | **13.6** | **13.7** | **13.8** | **14.0** | **0.0** |
| **OECD Asia** | **7.9** | **8.2** | **7.7** | **7.5** | **7.5** | **7.5** | **7.5** | **-0.3** |
| Japan | 4.4 | 4.7 | 3.9 | 3.7 | 3.7 | 3.6 | 3.4 | -1.2 |
| South Korea | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 0.3 |
| Australia and New Zealand | 1.2 | 1.2 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 0.8 |
| **Total OECD** | **46.0** | **45.5** | **45.8** | **45.5** | **45.5** | **45.7** | **46.1** | **0.0** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5.3** | **5.3** | **5.8** | **6.1** | **6.2** | **6.2** | **6.1** | **0.5** |
| Russia | 3.4 | 3.4 | 3.7 | 3.8 | 3.8 | 3.7 | 3.6 | 0.1 |
| Other | 1.9 | 1.8 | 2.2 | 2.3 | 2.4 | 2.5 | 2.5 | 1.2 |
| **Non-OECD Asia** | **20.5** | **21.5** | **26.7** | **29.4** | **32.2** | **35.4** | **38.9** | **2.1** |
| China | 9.5 | 10.2 | 12.7 | 13.8 | 14.8 | 15.7 | 16.4 | 1.7 |
| India | 3.5 | 3.6 | 4.5 | 5.2 | 5.9 | 7.0 | 8.3 | 3.0 |
| Other | 7.5 | 7.7 | 9.4 | 10.4 | 11.4 | 12.7 | 14.3 | 2.2 |
| **Middle East** | **7.4** | **7.7** | **10.0** | **10.4** | **11.3** | **12.3** | **13.2** | **2.0** |
| **Africa** | **3.4** | **3.6** | **4.5** | **5.1** | **5.5** | **6.1** | **6.9** | **2.4** |
| **Non-OECD Americas** | **6.4** | **6.7** | **7.5** | **8.0** | **8.5** | **9.0** | **9.6** | **1.3** |
| Brazil | 2.8 | 2.9 | 3.4 | 3.7 | 4.1 | 4.4 | 4.7 | 1.7 |
| Other | 3.6 | 3.8 | 4.1 | 4.3 | 4.4 | 4.6 | 4.9 | 0.9 |
| **Total Non-OECD** | **43.1** | **44.8** | **54.5** | **59.0** | **63.6** | **68.9** | **74.8** | **1.9** |
| **Total World** | **89.1** | **90.3** | **100.3** | **104.5** | **109.1** | **114.6** | **120.9** | **1.0** |

[a]Includes the 50 States and the District of Columbia.

Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table A6. World natural gas consumption by region, Reference case, 2011–40**
(trillion cubic feet)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **30.8** | **31.8** | **32.8** | **34.3** | **36.5** | **38.2** | **40.1** | **0.8** |
| United States[a] | 24.5 | 25.5 | 26.1 | 26.9 | 28.1 | 28.8 | 29.7 | 0.5 |
| Canada | 3.7 | 3.7 | 3.9 | 4.2 | 4.7 | 5.2 | 5.6 | 1.5 |
| Mexico and Chile | 2.6 | 2.6 | 2.8 | 3.2 | 3.6 | 4.2 | 4.8 | 2.2 |
| **OECD Europe** | **18.6** | **17.8** | **19.2** | **20.6** | **22.3** | **23.7** | **25.3** | **1.3** |
| **OECD Asia** | **7.6** | **7.9** | **8.9** | **9.8** | **10.4** | **11.3** | **12.2** | **1.6** |
| Japan | 4.5 | 4.7 | 5.1 | 5.6 | 5.7 | 5.9 | 6.0 | 0.9 |
| South Korea | 1.6 | 1.8 | 2.1 | 2.2 | 2.4 | 2.7 | 3.0 | 1.9 |
| Australia and New Zealand | 1.4 | 1.5 | 1.7 | 2.0 | 2.3 | 2.7 | 3.2 | 2.9 |
| **Total OECD** | **56.9** | **57.5** | **60.9** | **64.7** | **69.2** | **73.2** | **77.6** | **1.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **22.8** | **23.0** | **22.5** | **23.9** | **25.0** | **26.0** | **26.0** | **0.4** |
| Russia | 15.3 | 15.7 | 15.3 | 15.8 | 16.2 | 16.5 | 16.0 | 0.1 |
| Other | 7.5 | 7.3 | 7.2 | 8.1 | 8.9 | 9.5 | 10.0 | 1.1 |
| **Non-OECD Asia** | **14.6** | **15.1** | **20.8** | **27.2** | **34.0** | **42.5** | **50.8** | **4.4** |
| China | 4.6 | 5.1 | 9.1 | 13.5 | 17.6 | 22.7 | 27.5 | 6.2 |
| India | 2.3 | 2.1 | 2.3 | 2.9 | 3.8 | 4.9 | 6.0 | 3.9 |
| Other | 7.7 | 7.9 | 9.4 | 10.8 | 12.7 | 14.9 | 17.2 | 2.8 |
| **Middle East** | **13.9** | **14.7** | **17.7** | **20.5** | **23.5** | **26.1** | **28.9** | **2.5** |
| **Africa** | **3.9** | **4.5** | **5.5** | **6.2** | **7.7** | **9.4** | **11.1** | **3.3** |
| **Non-OECD Americas** | **5.0** | **5.1** | **5.8** | **6.5** | **7.2** | **8.0** | **8.9** | **2.0** |
| Brazil | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 1.9 | 2.2 | 2.6 |
| Other | 4.1 | 4.0 | 4.4 | 5.0 | 5.5 | 6.2 | 6.8 | 1.9 |
| **Total Non-OECD** | **60.3** | **62.3** | **72.3** | **84.4** | **97.5** | **112.0** | **125.7** | **2.5** |
| **Total World** | **117.1** | **119.8** | **133.2** | **149.1** | **166.6** | **185.2** | **203.3** | **1.9** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A7. World coal consumption by region, Reference case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **21.0** | **18.7** | **20.3** | **20.5** | **20.1** | **20.0** | **20.0** | **0.2** |
| United States[a] | 19.6 | 17.3 | 19.2 | 19.3 | 19.2 | 19.0 | 19.0 | 0.3 |
| Canada | 0.7 | 0.7 | 0.6 | 0.6 | 0.4 | 0.4 | 0.4 | -2.5 |
| Mexico and Chile | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.3 |
| **OECD Europe** | **12.9** | **13.4** | **13.2** | **13.3** | **13.1** | **12.8** | **12.6** | **-0.2** |
| **OECD Asia** | **9.7** | **9.7** | **10.2** | **10.1** | **10.1** | **10.1** | **10.1** | **0.1** |
| Japan | 4.3 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.0 | -0.5 |
| South Korea | 3.2 | 3.0 | 3.7 | 3.8 | 3.8 | 4.0 | 4.3 | 1.2 |
| Australia and New Zealand | 2.1 | 2.1 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | -0.4 |
| **Total OECD** | **43.6** | **41.8** | **43.7** | **44.0** | **43.3** | **42.9** | **42.7** | **0.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **9.6** | **10.2** | **9.4** | **9.4** | **9.6** | **9.8** | **9.6** | **-0.2** |
| Russia | 4.7 | 5.4 | 5.3 | 5.3 | 5.5 | 5.7 | 5.5 | 0.1 |
| Other | 5.0 | 4.8 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | -0.6 |
| **Non-OECD Asia** | **93.3** | **95.5** | **109.2** | **112.9** | **114.4** | **116.6** | **119.5** | **0.8** |
| China | 75.4 | 76.5 | 86.6 | 88.0 | 87.0 | 85.4 | 83.3 | 0.3 |
| India | 11.9 | 13.0 | 15.3 | 16.7 | 18.3 | 21.1 | 24.8 | 2.3 |
| Other | 5.9 | 6.1 | 7.4 | 8.3 | 9.1 | 10.1 | 11.5 | 2.3 |
| **Middle East** | **0.1** | **0.1** | **0.1** | **0.1** | **0.2** | **0.2** | **0.2** | **3.2** |
| **Africa** | **4.6** | **4.8** | **5.4** | **5.8** | **6.0** | **6.4** | **7.0** | **1.4** |
| **Non-OECD Americas** | **0.9** | **0.9** | **0.9** | **0.9** | **1.0** | **1.1** | **1.1** | **1.0** |
| Brazil | 0.5 | 0.6 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 |
| Other | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 1.3 |
| **Total Non-OECD** | **108.4** | **111.5** | **124.9** | **129.2** | **131.2** | **134.0** | **137.5** | **0.8** |
| **Total World** | **152.0** | **153.3** | **168.6** | **173.2** | **174.4** | **176.9** | **180.2** | **0.6** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A8. World nuclear energy consumption by region, Reference case, 2011–40
(billion kilowatthours)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **888** | **867** | **902** | **891** | **901** | **900** | **924** | **0.2** |
| United States[a] | 790 | 769 | 804 | 808 | 808 | 812 | 833 | 0.3 |
| Canada | 88 | 89 | 86 | 72 | 72 | 67 | 62 | -1.3 |
| Mexico and Chile | 9 | 8 | 12 | 12 | 20 | 20 | 29 | 4.5 |
| OECD Europe | **861** | **837** | **845** | **879** | **930** | **948** | **896** | **0.2** |
| OECD Asia | **304** | **161** | **381** | **437** | **457** | **450** | **427** | **3.5** |
| Japan | 156 | 17 | 167 | 180 | 175 | 169 | 146 | 7.9 |
| South Korea | 148 | 144 | 214 | 258 | 281 | 281 | 281 | 2.4 |
| Australia and New Zealand | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Total OECD | **2,053** | **1,865** | **2,128** | **2,208** | **2,287** | **2,298** | **2,246** | **0.7** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **275** | **279** | **376** | **415** | **411** | **412** | **413** | **1.4** |
| Russia | 162 | 166 | 234 | 267 | 239 | 228 | 223 | 1.0 |
| Other | 113 | 112 | 141 | 148 | 171 | 183 | 190 | 1.9 |
| Non-OECD Asia | **156** | **166** | **459** | **662** | **1,051** | **1,297** | **1,559** | **8.3** |
| China | 83 | 93 | 329 | 452 | 754 | 983 | 1,212 | 9.6 |
| India | 29 | 30 | 67 | 117 | 206 | 222 | 248 | 7.9 |
| Other | 44 | 44 | 63 | 93 | 92 | 92 | 98 | 2.9 |
| Middle East | **0** | **1** | **40** | **63** | **95** | **128** | **152** | **18.4** |
| Africa | **13** | **12** | **14** | **21** | **28** | **35** | **42** | **4.5** |
| Non-OECD Americas | **21** | **21** | **35** | **35** | **74** | **81** | **89** | **5.3** |
| Brazil | 15 | 15 | 23 | 23 | 54 | 54 | 54 | 4.7 |
| Other | 6 | 6 | 12 | 12 | 20 | 27 | 34 | 6.5 |
| Total Non-OECD | **465** | **480** | **924** | **1,196** | **1,659** | **1,953** | **2,255** | **5.7** |
| Total World | **2,518** | **2,345** | **3,051** | **3,404** | **3,946** | **4,251** | **4,501** | **2.4** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies.
**Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A9. World consumption of hydroelectricity and other renewable energy by region, Reference case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **13.1** | **12.9** | **15.6** | **16.6** | **17.5** | **18.6** | **20.3** | **1.6** |
| United States[a] | 7.9 | 7.7 | 9.3 | 9.7 | 9.9 | 10.4 | 11.3 | 1.4 |
| Canada | 4.3 | 4.2 | 4.8 | 5.1 | 5.5 | 5.8 | 6.3 | 1.4 |
| Mexico and Chile | 0.9 | 1.0 | 1.5 | 1.8 | 2.1 | 2.4 | 2.7 | 3.7 |
| **OECD Europe** | **10.7** | **11.5** | **15.7** | **16.7** | **17.3** | **18.5** | **19.6** | **1.9** |
| **OECD Asia** | **2.5** | **2.5** | **4.1** | **4.6** | **5.1** | **5.4** | **5.7** | **3.0** |
| Japan | 1.6 | 1.6 | 2.3 | 2.5 | 2.7 | 2.8 | 2.7 | 2.0 |
| South Korea | 0.2 | 0.2 | 0.7 | 0.8 | 1.0 | 1.1 | 1.2 | 7.1 |
| Australia and New Zealand | 0.7 | 0.7 | 1.2 | 1.2 | 1.4 | 1.5 | 1.8 | 3.2 |
| **Total OECD** | **26.3** | **27.0** | **35.5** | **37.9** | **39.8** | **42.5** | **45.5** | **1.9** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **3.0** | **3.0** | **3.4** | **3.8** | **4.0** | **4.3** | **4.4** | **1.4** |
| Russia | 1.7 | 1.7 | 1.8 | 2.2 | 2.4 | 2.5 | 2.5 | 1.3 |
| Other | 1.3 | 1.3 | 1.6 | 1.6 | 1.6 | 1.8 | 1.9 | 1.5 |
| **Non-OECD Asia** | **16.1** | **18.8** | **31.5** | **37.1** | **42.1** | **47.2** | **52.6** | **3.7** |
| China | 8.9 | 11.4 | 21.0 | 23.7 | 26.2 | 28.8 | 31.3 | 3.7 |
| India | 3.3 | 3.3 | 4.7 | 6.4 | 7.7 | 9.1 | 10.8 | 4.3 |
| Other | 3.9 | 4.1 | 5.8 | 7.1 | 8.2 | 9.3 | 10.5 | 3.4 |
| **Middle East** | **0.2** | **0.2** | **0.8** | **1.4** | **1.6** | **2.3** | **2.6** | **9.0** |
| **Africa** | **4.3** | **4.5** | **5.4** | **6.8** | **7.8** | **9.0** | **10.3** | **3.0** |
| **Non-OECD Americas** | **10.4** | **10.3** | **10.5** | **11.9** | **12.8** | **14.3** | **15.9** | **1.6** |
| Brazil | 7.0 | 6.8 | 7.0 | 8.0 | 8.6 | 9.8 | 11.1 | 1.7 |
| Other | 3.5 | 3.4 | 3.5 | 3.9 | 4.2 | 4.5 | 4.9 | 1.2 |
| **Total Non-OECD** | **34.1** | **36.8** | **51.5** | **60.9** | **68.3** | **77.0** | **85.8** | **3.1** |
| **Total World** | **60.4** | **63.8** | **87.0** | **98.8** | **108.1** | **119.5** | **131.4** | **2.6** |

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding. U.S. totals include net electricity imports, methanol, and liquid hydrogen. Other renewable energy includes wind, geothermal, solar, biomass, waste, and tide/wave/ocean.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). Projections: EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A10. World carbon dioxide emissions by region, Reference case, 2011–40
(million metric tons carbon dioxide)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **6,558** | **6,343** | **6,569** | **6,620** | **6,675** | **6,769** | **6,887** | **0.3** |
| United States[a] | 5,483 | 5,272 | 5,499 | 5,511 | 5,514 | 5,521 | 5,549 | 0.2 |
| Canada | 562 | 563 | 557 | 577 | 587 | 621 | 647 | 0.5 |
| Mexico and Chile | 513 | 508 | 513 | 533 | 573 | 628 | 690 | 1.1 |
| **OECD Europe** | **4,193** | **4,124** | **4,096** | **4,170** | **4,252** | **4,317** | **4,415** | **0.2** |
| **OECD Asia** | **2,270** | **2,322** | **2,361** | **2,388** | **2,407** | **2,460** | **2,513** | **0.3** |
| Japan | 1,185 | 1,247 | 1,176 | 1,175 | 1,159 | 1,144 | 1,111 | -0.4 |
| South Korea | 642 | 639 | 734 | 742 | 761 | 803 | 850 | 1.0 |
| Australia and New Zealand | 442 | 436 | 451 | 470 | 487 | 513 | 552 | 0.8 |
| **Total OECD** | **13,021** | **12,790** | **13,026** | **13,178** | **13,334** | **13,547** | **13,815** | **0.3** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **2,845** | **2,938** | **2,914** | **3,038** | **3,128** | **3,198** | **3,170** | **0.3** |
| Russia | 1,695 | 1,795 | 1,814 | 1,862 | 1,897 | 1,924 | 1,864 | 0.1 |
| Other | 1,150 | 1,143 | 1,100 | 1,176 | 1,231 | 1,275 | 1,306 | 0.5 |
| **Non-OECD Asia** | **11,785** | **12,195** | **14,456** | **15,505** | **16,386** | **17,482** | **18,682** | **1.5** |
| China | 8,119 | 8,378 | 9,861 | 10,371 | 10,636 | 10,878 | 11,051 | 1.0 |
| India | 1,663 | 1,778 | 2,143 | 2,394 | 2,693 | 3,161 | 3,732 | 2.7 |
| Other | 2,003 | 2,038 | 2,452 | 2,740 | 3,057 | 3,443 | 3,898 | 2.3 |
| **Middle East** | **1,828** | **1,894** | **2,399** | **2,608** | **2,887** | **3,171** | **3,446** | **2.2** |
| **Africa** | **1,120** | **1,184** | **1,438** | **1,594** | **1,760** | **1,973** | **2,239** | **2.3** |
| **Non-OECD Americas** | **1,242** | **1,271** | **1,398** | **1,509** | **1,608** | **1,725** | **1,865** | **1.4** |
| Brazil | 475 | 501 | 549 | 599 | 650 | 704 | 764 | 1.5 |
| Other | 767 | 769 | 849 | 910 | 958 | 1,021 | 1,101 | 1.3 |
| **Total Non-OECD** | **18,818** | **19,481** | **22,605** | **24,254** | **25,769** | **27,549** | **29,402** | **1.5** |
| **Total World** | **31,839** | **32,271** | **35,631** | **37,432** | **39,103** | **41,096** | **43,217** | **1.0** |

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding. The U.S. numbers include carbon dioxide emissions from electricty generation using nonbiogenic municipal solid waste and geothermal energy.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies.
**Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table A11. World carbon dioxide emissions from liquids use by region, Reference case, 2011–40**
(million metric tons carbon dioxide)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **2,881** | **2,838** | **2,861** | **2,812** | **2,785** | **2,794** | **2,812** | **0.0** |
| United States[a] | 2,291 | 2,240 | 2,269 | 2,227 | 2,182 | 2,163 | 2,147 | -0.2 |
| Canada | 289 | 291 | 291 | 289 | 290 | 295 | 304 | 0.2 |
| Mexico and Chile | 301 | 307 | 301 | 296 | 313 | 335 | 361 | 0.6 |
| **OECD Europe** | **1,969** | **1,903** | **1,823** | **1,804** | **1,815** | **1,832** | **1,854** | **-0.1** |
| **OECD Asia** | **942** | **980** | **912** | **897** | **892** | **892** | **891** | **-0.3** |
| Japan | 537 | 568 | 473 | 452 | 442 | 430 | 411 | -1.1 |
| South Korea | 248 | 253 | 263 | 264 | 267 | 272 | 280 | 0.4 |
| Australia and New Zealand | 157 | 160 | 176 | 181 | 184 | 189 | 199 | 0.8 |
| **Total OECD** | **5,792** | **5,721** | **5,595** | **5,513** | **5,492** | **5,517** | **5,557** | **-0.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **698** | **723** | **807** | **852** | **860** | **865** | **855** | **0.6** |
| Russia | 425 | 436 | 485 | 506 | 501 | 498 | 481 | 0.3 |
| Other | 273 | 286 | 322 | 346 | 358 | 366 | 374 | 1.0 |
| **Non-OECD Asia** | **2,706** | **2,786** | **3,501** | **3,854** | **4,219** | **4,632** | **5,090** | **2.2** |
| China | 1,257 | 1,306 | 1,665 | 1,806 | 1,932 | 2,038 | 2,124 | 1.8 |
| India | 414 | 435 | 573 | 657 | 756 | 889 | 1,055 | 3.2 |
| Other | 1,035 | 1,045 | 1,263 | 1,391 | 1,531 | 1,705 | 1,910 | 2.2 |
| **Middle East** | **1,050** | **1,068** | **1,401** | **1,452** | **1,560** | **1,696** | **1,814** | **1.9** |
| **Africa** | **481** | **495** | **639** | **714** | **776** | **858** | **977** | **2.5** |
| **Non-OECD Americas** | **878** | **902** | **990** | **1,052** | **1,106** | **1,170** | **1,251** | **1.2** |
| Brazil | 376 | 390 | 424 | 463 | 500 | 538 | 578 | 1.4 |
| Other | 502 | 512 | 566 | 589 | 606 | 632 | 672 | 1.0 |
| **Total Non-OECD** | **5,812** | **5,974** | **7,339** | **7,925** | **8,521** | **9,220** | **9,987** | **1.9** |
| **Total World** | **11,604** | **11,695** | **12,934** | **13,439** | **14,013** | **14,737** | **15,543** | **1.0** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A12. World carbon dioxide emissions from natural gas use by region, Reference case, 2011–40
(million metric tons carbon dioxide)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **1,666** | **1,715** | **1,766** | **1,849** | **1,965** | **2,063** | **2,167** | **0.8** |
| United States[a] | 1,305 | 1,363 | 1,394 | 1,432 | 1,497 | 1,538 | 1,586 | 0.5 |
| Canada | 205 | 205 | 213 | 234 | 261 | 287 | 310 | 1.5 |
| Mexico and Chile | 156 | 147 | 158 | 184 | 207 | 238 | 271 | 2.2 |
| **OECD Europe** | **1,016** | **970** | **1,046** | **1,122** | **1,218** | **1,291** | **1,383** | **1.3** |
| **OECD Asia** | **435** | **446** | **506** | **556** | **588** | **641** | **691** | **1.6** |
| Japan | 251 | 260 | 288 | 316 | 321 | 332 | 337 | 0.9 |
| South Korea | 98 | 105 | 126 | 131 | 140 | 160 | 177 | 1.9 |
| Australia and New Zealand | 86 | 80 | 92 | 109 | 127 | 149 | 177 | 2.9 |
| **Total OECD** | **3,117** | **3,131** | **3,317** | **3,527** | **3,771** | **3,995** | **4,241** | **1.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **1,240** | **1,255** | **1,227** | **1,301** | **1,364** | **1,416** | **1,415** | **0.4** |
| Russia | 834 | 855 | 835 | 860 | 881 | 897 | 871 | 0.1 |
| Other | 405 | 400 | 392 | 441 | 484 | 519 | 544 | 1.1 |
| **Non-OECD Asia** | **797** | **825** | **1,139** | **1,492** | **1,867** | **2,333** | **2,788** | **4.4** |
| China | 257 | 281 | 506 | 750 | 973 | 1,256 | 1,527 | 6.2 |
| India | 125 | 117 | 130 | 162 | 212 | 277 | 339 | 3.9 |
| Other | 415 | 426 | 504 | 580 | 682 | 800 | 923 | 2.8 |
| **Middle East** | **771** | **817** | **987** | **1,142** | **1,310** | **1,456** | **1,609** | **2.5** |
| **Africa** | **219** | **251** | **306** | **349** | **429** | **524** | **621** | **3.3** |
| **Non-OECD Americas** | **285** | **289** | **329** | **372** | **411** | **458** | **509** | **2.0** |
| Brazil | 50 | 60 | 76 | 84 | 94 | 106 | 122 | 2.6 |
| Other | 235 | 229 | 254 | 288 | 318 | 352 | 387 | 1.9 |
| **Total Non-OECD** | **3,312** | **3,436** | **3,989** | **4,656** | **5,382** | **6,188** | **6,943** | **2.5** |
| **Total World** | **6,429** | **6,566** | **7,306** | **8,183** | **9,153** | **10,183** | **11,184** | **1.9** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

# Table A13. World carbon dioxide emissions from coal use by region, Reference case, 2011–40
(million metric tons carbon dioxide)

| | History | | Projections | | | | | Average annual |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | percent change, 2012–40 |
| OECD | | | | | | | | |
| OECD Americas | **2,000** | **1,779** | **1,931** | **1,947** | **1,912** | **1,901** | **1,896** | **0.2** |
| United States[a] | 1,876 | 1,657 | 1,824 | 1,840 | 1,822 | 1,808 | 1,804 | 0.3 |
| Canada | 68 | 68 | 53 | 54 | 36 | 38 | 33 | -2.5 |
| Mexico and Chile | 56 | 54 | 53 | 53 | 54 | 55 | 58 | 0.3 |
| OECD Europe | **1,208** | **1,251** | **1,228** | **1,244** | **1,219** | **1,195** | **1,178** | **-0.2** |
| OECD Asia | **892** | **896** | **943** | **935** | **927** | **927** | **932** | **0.1** |
| Japan | 397 | 419 | 415 | 407 | 396 | 382 | 363 | -0.5 |
| South Korea | 296 | 281 | 345 | 347 | 355 | 371 | 394 | 1.2 |
| Australia and New Zealand | 199 | 196 | 183 | 180 | 177 | 174 | 176 | -0.4 |
| Total OECD | **4,100** | **3,926** | **4,102** | **4,126** | **4,058** | **4,023** | **4,005** | **0.1** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **907** | **961** | **880** | **885** | **904** | **917** | **900** | **-0.2** |
| Russia | 435 | 504 | 494 | 496 | 515 | 528 | 512 | 0.1 |
| Other | 472 | 457 | 386 | 389 | 389 | 389 | 388 | -0.6 |
| Non-OECD Asia | **8,282** | **8,584** | **9,816** | **10,159** | **10,300** | **10,518** | **10,804** | **0.8** |
| China | 6,605 | 6,791 | 7,690 | 7,815 | 7,731 | 7,585 | 7,400 | 0.3 |
| India | 1,124 | 1,226 | 1,441 | 1,574 | 1,726 | 1,995 | 2,338 | 2.3 |
| Other | 553 | 567 | 685 | 770 | 844 | 938 | 1,066 | 2.3 |
| Middle East | **7** | **9** | **11** | **14** | **17** | **19** | **22** | **3.2** |
| Africa | **420** | **438** | **493** | **531** | **555** | **590** | **641** | **1.4** |
| Non-OECD Americas | **79** | **80** | **78** | **84** | **90** | **97** | **105** | **1.0** |
| Brazil | 49 | 51 | 48 | 52 | 56 | 60 | 64 | 0.8 |
| Other | 30 | 29 | 30 | 32 | 34 | 37 | 41 | 1.3 |
| Total Non-OECD | **9,695** | **10,072** | **11,278** | **11,673** | **11,866** | **12,142** | **12,472** | **0.8** |
| Total World | **13,795** | **13,998** | **15,379** | **15,799** | **15,924** | **16,165** | **16,478** | **0.6** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies.
**Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table A14. World population by region, Reference case, 2011–40
(millions)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **484** | **489** | **523** | **544** | **564** | **581** | **597** | **0.7** |
| United States[a] | 312 | 315 | 334 | 347 | 359 | 370 | 380 | 0.7 |
| Canada | 34 | 35 | 38 | 39 | 41 | 43 | 44 | 0.8 |
| Mexico and Chile | 137 | 139 | 151 | 158 | 164 | 169 | 173 | 0.8 |
| **OECD Europe** | **548** | **550** | **565** | **571** | **576** | **579** | **581** | **0.2** |
| **OECD Asia** | **203** | **204** | **207** | **208** | **208** | **207** | **206** | **0.0** |
| Japan | 127 | 127 | 125 | 123 | 120 | 117 | 114 | -0.4 |
| South Korea | 49 | 49 | 51 | 52 | 52 | 52 | 52 | 0.2 |
| Australia and New Zealand | 27 | 27 | 31 | 33 | 36 | 38 | 40 | 1.3 |
| **Total OECD** | **1,235** | **1,243** | **1,295** | **1,323** | **1,348** | **1,368** | **1,384** | **0.4** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **343** | **343** | **343** | **341** | **337** | **333** | **329** | **-0.1** |
| Russia | 143 | 143 | 140 | 137 | 133 | 130 | 127 | -0.4 |
| Other | 199 | 200 | 203 | 204 | 204 | 203 | 203 | 0.1 |
| **Non-OECD Asia** | **3,691** | **3,730** | **4,013** | **4,159** | **4,278** | **4,373** | **4,443** | **0.6** |
| China | 1,373 | 1,381 | 1,435 | 1,450 | 1,453 | 1,448 | 1,434 | 0.1 |
| India | 1,229 | 1,244 | 1,360 | 1,425 | 1,482 | 1,530 | 1,569 | 0.8 |
| Other | 1,089 | 1,104 | 1,218 | 1,284 | 1,343 | 1,396 | 1,441 | 1.0 |
| **Middle East** | **210** | **214** | **249** | **271** | **293** | **316** | **340** | **1.7** |
| **Africa** | **1,045** | **1,070** | **1,284** | **1,429** | **1,583** | **1,745** | **1,916** | **2.1** |
| **Non-OECD Americas** | **467** | **473** | **515** | **540** | **562** | **583** | **601** | **0.9** |
| Brazil | 198 | 200 | 212 | 218 | 223 | 227 | 230 | 0.5 |
| Other | 270 | 273 | 304 | 322 | 339 | 356 | 372 | 1.1 |
| **Total Non-OECD** | **5,756** | **5,830** | **6,404** | **6,739** | **7,054** | **7,351** | **7,630** | **1.0** |
| **Total World** | **6,991** | **7,073** | **7,699** | **8,063** | **8,402** | **8,719** | **9,014** | **0.9** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2013 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

Appendix B

# High Economic Growth case projections

## Table B1. World total primary energy consumption by region, High Economic Growth case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **120.6** | **118.1** | **128.2** | **132.3** | **137.0** | **142.4** | **150.1** | **0.9** |
| United States[a] | 96.8 | 94.4 | 103.1 | 105.9 | 108.5 | 111.4 | 116.2 | 0.7 |
| Canada | 14.5 | 14.5 | 15.1 | 15.8 | 16.6 | 17.6 | 18.8 | 0.9 |
| Mexico and Chile | 9.3 | 9.2 | 9.9 | 10.7 | 11.9 | 13.4 | 15.1 | 1.8 |
| OECD Europe | **82.0** | **81.4** | **85.4** | **88.7** | **92.3** | **95.8** | **99.3** | **0.7** |
| OECD Asia | **39.4** | **39.0** | **43.6** | **45.9** | **47.3** | **49.0** | **50.5** | **0.9** |
| Japan | 21.2 | 20.8 | 22.0 | 22.8 | 22.8 | 22.8 | 22.2 | 0.2 |
| South Korea | 11.3 | 11.4 | 14.0 | 14.9 | 15.8 | 16.7 | 17.7 | 1.6 |
| Australia and New Zealand | 6.9 | 6.8 | 7.6 | 8.2 | 8.7 | 9.5 | 10.6 | 1.6 |
| Total OECD | **242.0** | **238.4** | **257.2** | **266.9** | **276.5** | **287.2** | **299.9** | **0.8** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **49.9** | **50.7** | **52.0** | **55.1** | **56.9** | **58.7** | **58.8** | **0.5** |
| Russia | 30.9 | 32.1 | 33.3 | 35.0 | 35.6 | 36.2 | 35.4 | 0.4 |
| Other | 19.0 | 18.6 | 18.7 | 20.1 | 21.4 | 22.5 | 23.3 | 0.8 |
| Non-OECD Asia | **168.2** | **175.9** | **225.0** | **252.3** | **279.7** | **309.8** | **342.5** | **2.4** |
| China | 109.4 | 115.0 | 148.9 | 163.9 | 177.6 | 190.7 | 203.3 | 2.1 |
| India | 25.0 | 26.2 | 33.1 | 39.1 | 46.0 | 54.5 | 64.8 | 3.3 |
| Other | 33.7 | 34.7 | 43.0 | 49.3 | 56.1 | 64.5 | 74.4 | 2.8 |
| Middle East | **29.9** | **31.7** | **41.2** | **46.6** | **52.7** | **59.6** | **66.2** | **2.7** |
| Africa | **20.1** | **21.5** | **26.3** | **30.4** | **34.4** | **39.4** | **45.4** | **2.7** |
| Non-OECD Americas | **30.5** | **31.0** | **33.8** | **37.4** | **40.8** | **44.9** | **49.6** | **1.7** |
| Brazil | 14.8 | 15.2 | 16.4 | 18.5 | 20.5 | 22.9 | 25.5 | 1.9 |
| Other | 15.7 | 15.8 | 17.4 | 18.9 | 20.3 | 22.1 | 24.1 | 1.5 |
| Total Non-OECD | **298.6** | **310.8** | **378.3** | **421.7** | **464.6** | **512.3** | **562.4** | **2.1** |
| Total World | **540.5** | **549.3** | **635.5** | **688.6** | **741.1** | **799.6** | **862.3** | **1.6** |

[a]Includes the 50 States and the District of Columbia.
Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run HIGHMACRO.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-macro_high_2016.02.19_115030.

## Table B2. World gross domestic product (GDP) by region expressed in purchasing power parity, High Economic Growth case, 2011–40
(billion 2010 dollars)

| Region | History | | Projections | | | | | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | |
| OECD | | | | | | | | |
| **OECD Americas** | **18,616** | **19,080** | **24,230** | **28,258** | **32,427** | **36,956** | **42,539** | **2.9** |
| United States[a] | 15,021 | 15,369 | 19,590 | 22,852 | 26,146 | 29,678 | 34,146 | 2.9 |
| Canada | 1,396 | 1,422 | 1,717 | 1,921 | 2,143 | 2,398 | 2,680 | 2.3 |
| Mexico and Chile | 2,200 | 2,288 | 2,923 | 3,485 | 4,138 | 4,880 | 5,713 | 3.3 |
| **OECD Europe** | **18,670** | **18,638** | **21,717** | **24,201** | **26,671** | **29,224** | **31,986** | **1.9** |
| **OECD Asia** | **6,904** | **7,051** | **8,112** | **8,813** | **9,405** | **10,107** | **10,797** | **1.5** |
| Japan | 4,299 | 4,373 | 4,735 | 5,037 | 5,191 | 5,379 | 5,458 | 0.8 |
| South Korea | 1,528 | 1,563 | 1,984 | 2,191 | 2,418 | 2,669 | 2,946 | 2.3 |
| Australia and New Zealand | 1,077 | 1,115 | 1,393 | 1,586 | 1,796 | 2,059 | 2,393 | 2.8 |
| **Total OECD** | **44,189** | **44,769** | **54,059** | **61,273** | **68,503** | **76,287** | **85,322** | **2.3** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5,380** | **5,535** | **6,660** | **7,885** | **9,222** | **10,765** | **12,356** | **2.9** |
| Russia | 3,165 | 3,273 | 3,678 | 4,199 | 4,772 | 5,436 | 6,008 | 2.2 |
| Other | 2,215 | 2,262 | 2,983 | 3,686 | 4,449 | 5,329 | 6,348 | 3.8 |
| **Non-OECD Asia** | **26,261** | **27,914** | **44,786** | **57,945** | **72,832** | **90,113** | **110,412** | **5.0** |
| China | 13,286 | 14,309 | 23,591 | 30,694 | 38,509 | 47,203 | 56,956 | 5.1 |
| India | 5,706 | 5,957 | 10,318 | 13,805 | 17,844 | 22,733 | 28,711 | 5.8 |
| Other | 7,268 | 7,648 | 10,878 | 13,446 | 16,478 | 20,177 | 24,744 | 4.3 |
| **Middle East** | **4,986** | **5,072** | **7,098** | **8,917** | **10,913** | **13,124** | **15,570** | **4.1** |
| **Africa** | **4,355** | **4,561** | **6,610** | **8,460** | **10,861** | **13,967** | **17,926** | **5.0** |
| **Non-OECD Americas** | **6,427** | **6,604** | **8,067** | **9,503** | **10,968** | **12,593** | **14,479** | **2.8** |
| Brazil | 2,916 | 2,968 | 3,462 | 4,063 | 4,683 | 5,359 | 6,123 | 2.6 |
| Other | 3,510 | 3,636 | 4,605 | 5,441 | 6,285 | 7,234 | 8,356 | 3.0 |
| **Total Non-OECD** | **47,408** | **49,686** | **73,223** | **92,710** | **114,795** | **140,563** | **170,743** | **4.5** |
| **Total World** | **91,598** | **94,455** | **127,282** | **153,982** | **183,298** | **216,849** | **256,065** | **3.6** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run HIGHMACRO.D021915A, www.eia.gov/aeo.

Appendix C

# Low Economic Growth case projections

## Table C1. World total primary energy consumption by region, Low Economic Growth case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **120.6** | **118.1** | **123.3** | **123.9** | **124.7** | **126.3** | **128.8** | **0.3** |
| United States[a] | 96.8 | 94.4 | 98.7 | 98.1 | 97.5 | 97.4 | 98.0 | 0.1 |
| Canada | 14.5 | 14.5 | 15.0 | 15.4 | 15.9 | 16.6 | 17.3 | 0.6 |
| Mexico and Chile | 9.3 | 9.2 | 9.7 | 10.3 | 11.2 | 12.3 | 13.5 | 1.4 |
| **OECD Europe** | **82.0** | **81.4** | **84.0** | **86.3** | **88.4** | **90.4** | **91.7** | **0.4** |
| **OECD Asia** | **39.4** | **39.0** | **43.0** | **44.3** | **45.1** | **46.0** | **46.3** | **0.6** |
| Japan | 21.2 | 20.8 | 21.7 | 22.0 | 21.8 | 21.6 | 20.8 | 0.0 |
| South Korea | 11.3 | 11.4 | 13.7 | 14.4 | 15.0 | 15.5 | 15.9 | 1.2 |
| Australia and New Zealand | 6.9 | 6.8 | 7.5 | 7.9 | 8.3 | 8.9 | 9.6 | 1.2 |
| **Total OECD** | **242.0** | **238.4** | **250.4** | **254.5** | **258.2** | **262.6** | **266.8** | **0.4** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **49.9** | **50.7** | **51.7** | **54.4** | **55.9** | **57.0** | **56.4** | **0.4** |
| Russia | 30.9 | 32.1 | 33.0 | 34.3 | 34.6 | 34.7 | 33.4 | 0.1 |
| Other | 19.0 | 18.6 | 18.6 | 20.0 | 21.3 | 22.3 | 23.0 | 0.8 |
| **Non-OECD Asia** | **168.2** | **175.9** | **220.3** | **240.8** | **260.1** | **280.1** | **296.4** | **1.9** |
| China | 109.4 | 115.0 | 145.6 | 155.2 | 163.3 | 170.5 | 172.5 | 1.5 |
| India | 25.0 | 26.2 | 32.4 | 37.7 | 43.7 | 50.9 | 59.5 | 3.0 |
| Other | 33.7 | 34.7 | 42.3 | 47.8 | 53.1 | 58.8 | 64.4 | 2.2 |
| **Middle East** | **29.9** | **31.7** | **40.4** | **44.3** | **48.7** | **53.4** | **57.2** | **2.1** |
| **Africa** | **20.1** | **21.5** | **25.9** | **29.6** | **33.2** | **37.5** | **42.6** | **2.5** |
| **Non-OECD Americas** | **30.5** | **31.0** | **33.1** | **36.1** | **38.6** | **41.6** | **44.9** | **1.3** |
| Brazil | 14.8 | 15.2 | 16.1 | 17.8 | 19.4 | 21.2 | 23.1 | 1.5 |
| Other | 15.7 | 15.8 | 17.0 | 18.3 | 19.2 | 20.4 | 21.8 | 1.2 |
| **Total Non-OECD** | **298.6** | **310.8** | **371.5** | **405.2** | **436.4** | **469.6** | **497.5** | **1.7** |
| **Total World** | **540.5** | **549.3** | **621.9** | **659.6** | **694.7** | **732.3** | **764.3** | **1.2** |

[a]Includes the 50 States and the District of Columbia.

Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run LowMACRO. D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run macro_low_2016.02.19_115022.

# Table C2. World gross domestic product (GDP) by region expressed in purchasing power parity, Low Economic Growth case, 2011–40

(billion 2010 dollars)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **18,616** | **19,080** | **22,285** | **24,599** | **27,041** | **29,850** | **33,088** | **2.0** |
| United States[a] | 15,021 | 15,369 | 17,747 | 19,441 | 21,224 | 23,305 | 25,763 | 1.9 |
| Canada | 1,396 | 1,422 | 1,682 | 1,841 | 2,005 | 2,186 | 2,375 | 1.8 |
| Mexico and Chile | 2,200 | 2,288 | 2,856 | 3,317 | 3,813 | 4,358 | 4,950 | 2.8 |
| **OECD Europe** | **18,670** | **18,638** | **21,243** | **23,064** | **24,754** | **26,420** | **28,088** | **1.5** |
| **OECD Asia** | **6,904** | **7,051** | **7,923** | **8,363** | **8,768** | **9,208** | **9,579** | **1.1** |
| Japan | 4,299 | 4,373 | 4,625 | 4,761 | 4,846 | 4,920 | 4,896 | 0.4 |
| South Korea | 1,528 | 1,563 | 1,934 | 2,081 | 2,239 | 2,405 | 2,555 | 1.8 |
| Australia and New Zealand | 1,077 | 1,115 | 1,365 | 1,521 | 1,683 | 1,884 | 2,127 | 2.3 |
| **Total OECD** | **44,189** | **44,769** | **51,451** | **56,026** | **60,564** | **65,478** | **70,755** | **1.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5,380** | **5,535** | **6,562** | **7,641** | **8,793** | **10,087** | **11,331** | **2.6** |
| Russia | 3,165 | 3,273 | 3,610 | 4,017 | 4,433 | 4,892 | 5,195 | 1.7 |
| Other | 2,215 | 2,262 | 2,952 | 3,624 | 4,359 | 5,195 | 6,136 | 3.6 |
| **Non-OECD Asia** | **26,261** | **27,914** | **43,489** | **54,543** | **66,290** | **79,176** | **91,493** | **4.3** |
| China | 13,286 | 14,309 | 22,731 | 28,382 | 34,119 | 40,094 | 44,582 | 4.1 |
| India | 5,706 | 5,957 | 10,011 | 13,039 | 16,406 | 20,344 | 25,009 | 5.3 |
| Other | 7,268 | 7,648 | 10,747 | 13,122 | 15,765 | 18,738 | 21,902 | 3.8 |
| **Middle East** | **4,986** | **5,072** | **6,803** | **8,240** | **9,707** | **11,205** | **12,705** | **3.3** |
| **Africa** | **4,355** | **4,561** | **6,468** | **8,131** | **10,258** | **12,968** | **16,365** | **4.7** |
| **Non-OECD Americas** | **6,427** | **6,604** | **7,838** | **9,014** | **10,153** | **11,376** | **12,761** | **2.4** |
| Brazil | 2,916 | 2,968 | 3,359 | 3,836 | 4,305 | 4,795 | 5,333 | 2.1 |
| Other | 3,510 | 3,636 | 4,479 | 5,178 | 5,848 | 6,580 | 7,428 | 2.6 |
| **Total Non-OECD** | **47,408** | **49,686** | **71,160** | **87,570** | **105,200** | **124,812** | **144,655** | **3.9** |
| **Total World** | **91,598** | **94,455** | **122,612** | **143,596** | **165,763** | **190,290** | **215,409** | **3.0** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run LOWMACRO.D021915A, www.eia.gov/aeo.

Appendix D

# High Oil Price case projections

## Table D1. World total primary energy consumption by region, High Oil Price case, 2011–40
(quadrillion Btu)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **120.6** | **118.1** | **125.3** | **127.9** | **130.8** | **135.5** | **142.1** | **0.7** |
| United States[a] | 96.8 | 94.4 | 100.8 | 102.2 | 103.3 | 105.7 | 109.7 | 0.5 |
| Canada | 14.5 | 14.5 | 15.0 | 15.5 | 16.2 | 17.1 | 18.2 | 0.8 |
| Mexico and Chile | 9.3 | 9.2 | 9.5 | 10.2 | 11.4 | 12.7 | 14.3 | 1.6 |
| **OECD Europe** | **82.0** | **81.4** | **83.6** | **86.3** | **89.3** | **92.5** | **95.8** | **0.6** |
| **OECD Asia** | **39.4** | **39.0** | **42.3** | **44.1** | **45.5** | **47.0** | **48.5** | **0.8** |
| Japan | 21.2 | 20.8 | 21.3 | 21.9 | 21.9 | 22.0 | 21.5 | 0.1 |
| South Korea | 11.3 | 11.4 | 13.5 | 14.3 | 15.1 | 15.9 | 16.8 | 1.4 |
| Australia and New Zealand | 6.9 | 6.8 | 7.5 | 8.0 | 8.4 | 9.1 | 10.1 | 1.4 |
| Total OECD | **242.0** | **238.4** | **251.2** | **258.4** | **265.6** | **275.0** | **286.4** | **0.7** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **49.9** | **50.7** | **51.2** | **54.4** | **56.2** | **58.0** | **58.1** | **0.5** |
| Russia | 30.9 | 32.1 | 32.7 | 34.5 | 35.1 | 35.7 | 34.9 | 0.3 |
| Other | 19.0 | 18.6 | 18.5 | 19.9 | 21.2 | 22.3 | 23.2 | 0.8 |
| **Non-OECD Asia** | **168.2** | **175.9** | **220.3** | **247.8** | **275.8** | **307.1** | **340.8** | **2.4** |
| China | 109.4 | 115.0 | 146.5 | 161.6 | 175.8 | 190.0 | 203.3 | 2.1 |
| India | 25.0 | 26.2 | 32.1 | 38.2 | 45.1 | 53.6 | 63.7 | 3.2 |
| Other | 33.7 | 34.7 | 41.6 | 48.0 | 54.9 | 63.5 | 73.7 | 2.7 |
| **Middle East** | **29.9** | **31.7** | **40.5** | **46.1** | **52.6** | **59.9** | **66.9** | **2.7** |
| **Africa** | **20.1** | **21.5** | **25.3** | **29.6** | **33.8** | **38.9** | **45.0** | **2.7** |
| **Non-OECD Americas** | **30.5** | **31.0** | **32.6** | **36.4** | **40.1** | **44.4** | **49.3** | **1.7** |
| Brazil | 14.8 | 15.2 | 15.8 | 18.0 | 20.2 | 22.7 | 25.4 | 1.8 |
| Other | 15.7 | 15.8 | 16.8 | 18.4 | 19.9 | 21.7 | 23.9 | 1.5 |
| Total Non-OECD | **298.6** | **310.8** | **369.8** | **414.3** | **458.5** | **508.1** | **560.1** | **2.1** |
| Total World | **540.5** | **549.3** | **621.0** | **672.7** | **724.1** | **783.1** | **846.5** | **1.6** |

[a]Includes the 50 States and the District of Columbia.

Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run HIGHPRICE.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-oil_price_high_2016.02.19_115017.

## Table D2. World gross domestic product (GDP) by region expressed in purchasing power parity, High Oil Price case, 2011–40
(billion 2010 dollars)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **18,616** | **19,080** | **23,389** | **26,786** | **29,906** | **33,492** | **37,662** | **2.5** |
| United States[a] | 15,021 | 15,369 | 18,798 | 21,497 | 23,844 | 26,561 | 29,760 | 2.4 |
| Canada | 1,396 | 1,422 | 1,700 | 1,882 | 2,076 | 2,295 | 2,536 | 2.1 |
| Mexico and Chile | 2,200 | 2,288 | 2,891 | 3,406 | 3,986 | 4,636 | 5,365 | 3.1 |
| **OECD Europe** | **18,670** | **18,638** | **21,501** | **23,641** | **25,738** | **27,885** | **30,194** | **1.7** |
| **OECD Asia** | **6,904** | **7,051** | **8,031** | **8,576** | **9,093** | **9,655** | **10,218** | **1.3** |
| Japan | 4,299 | 4,373 | 4,693 | 4,883 | 5,018 | 5,132 | 5,163 | 0.6 |
| South Korea | 1,528 | 1,563 | 1,959 | 2,137 | 2,333 | 2,547 | 2,784 | 2.1 |
| Australia and New Zealand | 1,077 | 1,115 | 1,379 | 1,555 | 1,742 | 1,976 | 2,271 | 2.6 |
| **Total OECD** | **44,189** | **44,769** | **52,922** | **59,002** | **64,736** | **71,032** | **78,073** | **2.0** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5,380** | **5,535** | **6,636** | **7,832** | **9,144** | **10,668** | **12,228** | **2.9** |
| Russia | 3,165 | 3,273 | 3,664 | 4,168 | 4,721 | 5,369 | 5,927 | 2.1 |
| Other | 2,215 | 2,262 | 2,972 | 3,664 | 4,423 | 5,298 | 6,301 | 3.7 |
| **Non-OECD Asia** | **26,261** | **27,914** | **44,642** | **57,714** | **72,523** | **89,841** | **110,225** | **5.0** |
| China | 13,286 | 14,309 | 23,486 | 30,532 | 38,280 | 46,990 | 56,784 | 5.0 |
| India | 5,706 | 5,957 | 10,318 | 13,805 | 17,844 | 22,733 | 28,711 | 5.8 |
| Other | 7,268 | 7,648 | 10,838 | 13,378 | 16,399 | 20,118 | 24,730 | 4.3 |
| **Middle East** | **4,986** | **5,072** | **7,097** | **8,915** | **10,913** | **13,128** | **15,578** | **4.1** |
| **Africa** | **4,355** | **4,561** | **6,610** | **8,459** | **10,859** | **13,964** | **17,922** | **5.0** |
| **Non-OECD Americas** | **6,427** | **6,604** | **8,069** | **9,508** | **10,975** | **12,604** | **14,495** | **2.8** |
| Brazil | 2,916 | 2,968 | 3,462 | 4,063 | 4,683 | 5,359 | 6,123 | 2.6 |
| Other | 3,510 | 3,636 | 4,607 | 5,445 | 6,292 | 7,244 | 8,371 | 3.0 |
| **Total Non-OECD** | **47,408** | **49,686** | **73,054** | **92,428** | **114,414** | **140,205** | **170,448** | **4.5** |
| **Total World** | **91,598** | **94,455** | **125,976** | **151,430** | **179,151** | **211,237** | **248,521** | **3.5** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run HIGHPRICE.D021915A, www.eia.gov/aeo.

## Table D3. World liquids consumption by region, High Oil Price case, 2011–40
(million barrels per day)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| OECD Americas | **23.6** | **23.2** | **23.6** | **23.2** | **22.9** | **22.8** | **23.1** | **0.0** |
| United States[a] | 18.9 | 18.5 | 19.0 | 18.6 | 18.0 | 17.7 | 17.7 | -0.2 |
| Canada | 2.3 | 2.4 | 2.3 | 2.3 | 2.4 | 2.5 | 2.6 | 0.3 |
| Mexico and Chile | 2.4 | 2.4 | 2.3 | 2.3 | 2.4 | 2.6 | 2.8 | 0.6 |
| OECD Europe | **14.5** | **14.1** | **13.3** | **13.2** | **13.4** | **13.5** | **13.6** | **-0.1** |
| OECD Asia | **7.9** | **8.2** | **7.3** | **7.2** | **7.2** | **7.3** | **7.4** | **-0.4** |
| Japan | 4.4 | 4.7 | 3.7 | 3.5 | 3.5 | 3.4 | 3.3 | -1.2 |
| South Korea | 2.3 | 2.3 | 2.2 | 2.3 | 2.3 | 2.4 | 2.5 | 0.2 |
| Australia and New Zealand | 1.2 | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 0.8 |
| Total OECD | **46.0** | **45.5** | **44.1** | **43.7** | **43.4** | **43.6** | **44.1** | **-0.1** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **5.3** | **5.3** | **5.6** | **6.0** | **6.1** | **6.1** | **6.1** | **0.5** |
| Russia | 3.4 | 3.4 | 3.5 | 3.7 | 3.7 | 3.7 | 3.6 | 0.1 |
| Other | 1.9 | 1.8 | 2.1 | 2.3 | 2.4 | 2.5 | 2.5 | 1.2 |
| Non-OECD Asia | **20.5** | **21.5** | **25.8** | **28.6** | **31.3** | **34.6** | **38.0** | **2.1** |
| China | 9.5 | 10.2 | 12.4 | 13.8 | 14.9 | 16.2 | 17.1 | 1.9 |
| India | 3.5 | 3.6 | 4.3 | 4.9 | 5.6 | 6.4 | 7.4 | 2.6 |
| Other | 7.5 | 7.7 | 9.0 | 9.9 | 10.8 | 12.0 | 13.5 | 2.0 |
| Middle East | **7.4** | **7.7** | **9.8** | **10.4** | **11.5** | **12.8** | **14.1** | **2.2** |
| Africa | **3.4** | **3.6** | **4.4** | **4.9** | **5.4** | **6.1** | **7.0** | **2.4** |
| Non-OECD Americas | **6.4** | **6.7** | **7.2** | **7.7** | **8.1** | **8.6** | **9.2** | **1.2** |
| Brazil | 2.8 | 2.9 | 3.2 | 3.6 | 3.9 | 4.2 | 4.6 | 1.6 |
| Other | 3.6 | 3.8 | 4.0 | 4.1 | 4.2 | 4.4 | 4.6 | 0.8 |
| Total Non-OECD | **43.1** | **44.8** | **52.8** | **57.6** | **62.4** | **68.2** | **74.4** | **1.8** |
| Total World | **89.1** | **90.3** | **96.9** | **101.2** | **105.8** | **111.8** | **118.5** | **1.0** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies.
**Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run HIGHPRICE.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-oil_price_high_2016.02.19_115017.

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Appendix E

# Low Oil Price case projections

**Table E1. World total primary energy consumption by region, Low Oil Price case, 2011–40**
(quadrillion Btu)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–s40 |
| OECD | | | | | | | | |
| **OECD Americas** | **120.6** | **118.1** | **126.5** | **129.2** | **131.8** | **135.0** | **138.9** | **0.6** |
| United States[a] | 96.8 | 94.4 | 101.2 | 102.7 | 103.6 | 104.6 | 106.1 | 0.4 |
| Canada | 14.5 | 14.5 | 15.3 | 15.8 | 16.5 | 17.4 | 18.3 | 0.8 |
| Mexico and Chile | 9.3 | 9.2 | 10.0 | 10.7 | 11.8 | 13.0 | 14.5 | 1.6 |
| **OECD Europe** | **82.0** | **81.4** | **85.4** | **88.1** | **91.1** | **94.1** | **96.5** | **0.6** |
| **OECD Asia** | **39.4** | **39.0** | **43.9** | **45.6** | **46.8** | **48.2** | **48.9** | **0.8** |
| Japan | 21.2 | 20.8 | 22.1 | 22.6 | 22.7 | 22.6 | 21.8 | 0.2 |
| South Korea | 11.3 | 11.4 | 14.1 | 14.9 | 15.6 | 16.4 | 17.0 | 1.4 |
| Australia and New Zealand | 6.9 | 6.8 | 7.6 | 8.1 | 8.5 | 9.2 | 10.1 | 1.4 |
| **Total OECD** | **242.0** | **238.4** | **255.8** | **262.9** | **269.8** | **277.3** | **284.4** | **0.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **49.9** | **50.7** | **52.0** | **54.7** | **56.3** | **57.5** | **57.0** | **0.4** |
| Russia | 30.9 | 32.1 | 33.3 | 34.6 | 35.0 | 35.2 | 33.9 | 0.2 |
| Other | 19.0 | 18.6 | 18.8 | 20.1 | 21.4 | 22.4 | 23.1 | 0.8 |
| **Non-OECD Asia** | **168.2** | **175.9** | **223.2** | **243.7** | **263.6** | **284.1** | **300.5** | **1.9** |
| China | 109.4 | 115.0 | 147.0 | 156.6 | 165.0 | 172.3 | 173.9 | 1.5 |
| India | 25.0 | 26.2 | 32.9 | 38.2 | 44.3 | 51.7 | 60.5 | 3.0 |
| Other | 33.7 | 34.7 | 43.3 | 48.9 | 54.3 | 60.1 | 66.1 | 2.3 |
| **Middle East** | **29.9** | **31.7** | **41.5** | **45.2** | **49.9** | **54.8** | **59.0** | **2.2** |
| **Africa** | **20.1** | **21.5** | **26.5** | **30.2** | **33.9** | **38.4** | **43.8** | **2.6** |
| **Non-OECD Americas** | **30.5** | **31.0** | **34.0** | **36.8** | **39.5** | **42.6** | **46.2** | **1.4** |
| Brazil | 14.8 | 15.2 | 16.5 | 18.2 | 19.8 | 21.7 | 23.8 | 1.6 |
| Other | 15.7 | 15.8 | 17.5 | 18.7 | 19.7 | 20.9 | 22.4 | 1.3 |
| **Total Non-OECD** | **298.6** | **310.8** | **377.1** | **410.7** | **443.2** | **477.5** | **506.5** | **1.8** |
| **Total World** | **540.5** | **549.3** | **632.9** | **673.6** | **713.0** | **754.8** | **790.9** | **1.3** |

[a]Includes the 50 States and the District of Columbia.
Notes: Energy totals include net imports of coal coke and electricity generated from biomass in the United States. Totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run LOWPRICE.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-oil_price_low_2016.02.19_115103.

## Table E2. World gross domestic product (GDP) by region expressed in purchasing power parity, Low Oil Price case, 2011–40
(billion 2010 dollars)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **18,616** | **19,080** | **23,330** | **26,574** | **29,998** | **33,626** | **37,702** | **2.5** |
| United States[a] | 15,021 | 15,369 | 18,742 | 21,299 | 23,963 | 26,735 | 29,885 | 2.4 |
| Canada | 1,396 | 1,422 | 1,700 | 1,881 | 2,073 | 2,290 | 2,521 | 2.1 |
| Mexico and Chile | 2,200 | 2,288 | 2,889 | 3,394 | 3,962 | 4,601 | 5,296 | 3.0 |
| **OECD Europe** | **18,670** | **18,638** | **21,493** | **23,604** | **25,662** | **27,741** | **29,880** | **1.7** |
| **OECD Asia** | **6,904** | **7,051** | **8,036** | **8,576** | **9,094** | **9,644** | **10,108** | **1.3** |
| Japan | 4,299 | 4,373 | 4,697 | 4,890 | 5,032 | 5,151 | 5,159 | 0.6 |
| South Korea | 1,528 | 1,563 | 1,961 | 2,134 | 2,324 | 2,527 | 2,703 | 2.0 |
| Australia and New Zealand | 1,077 | 1,115 | 1,379 | 1,552 | 1,737 | 1,966 | 2,247 | 2.5 |
| **Total OECD** | **44,189** | **44,769** | **52,859** | **58,754** | **64,753** | **71,012** | **77,690** | **2.0** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5,380** | **5,535** | **6,591** | **7,693** | **8,858** | **10,169** | **11,432** | **2.6** |
| Russia | 3,165 | 3,273 | 3,626 | 4,047 | 4,473 | 4,939 | 5,249 | 1.7 |
| Other | 2,215 | 2,262 | 2,965 | 3,646 | 4,385 | 5,230 | 6,183 | 3.7 |
| **Non-OECD Asia** | **26,261** | **27,914** | **43,635** | **54,750** | **66,564** | **79,429** | **91,901** | **4.3** |
| China | 13,286 | 14,309 | 22,824 | 28,516 | 34,327 | 40,319 | 44,931 | 4.2 |
| India | 5,706 | 5,957 | 10,011 | 13,039 | 16,406 | 20,344 | 25,009 | 5.3 |
| Other | 7,268 | 7,648 | 10,801 | 13,195 | 15,831 | 18,765 | 21,962 | 3.8 |
| **Middle East** | **4,986** | **5,072** | **6,805** | **8,241** | **9,705** | **11,200** | **12,697** | **3.3** |
| **Africa** | **4,355** | **4,561** | **6,469** | **8,132** | **10,259** | **12,969** | **16,367** | **4.7** |
| **Non-OECD Americas** | **6,427** | **6,604** | **7,835** | **9,010** | **10,147** | **11,367** | **12,747** | **2.4** |
| Brazil | 2,916 | 2,968 | 3,359 | 3,836 | 4,305 | 4,795 | 5,333 | 2.1 |
| Other | 3,510 | 3,636 | 4,476 | 5,174 | 5,843 | 6,572 | 7,414 | 2.6 |
| **Total Non-OECD** | **47,408** | **49,686** | **71,335** | **87,826** | **105,533** | **125,134** | **145,145** | **3.9** |
| **Total World** | **91,598** | **94,455** | **124,194** | **146,579** | **170,286** | **196,146** | **222,835** | **3.1** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Derived from Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run LowPRICE.D021915A, www.eia.gov/aeo.

**Table E3. World liquids consumption by region, Low Oil Price case, 2011–40**
(million barrels per day)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **23.6** | **23.2** | **24.9** | **25.0** | **25.2** | **25.5** | **26.1** | **0.4** |
| United States[a] | 18.9 | 18.5 | 20.0 | 20.1 | 20.1 | 20.2 | 20.4 | 0.4 |
| Canada | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 | 2.6 | 2.6 | 0.4 |
| Mexico and Chile | 2.4 | 2.4 | 2.5 | 2.5 | 2.6 | 2.8 | 3.1 | 0.8 |
| **OECD Europe** | **14.5** | **14.1** | **14.0** | **13.9** | **14.0** | **14.2** | **14.4** | **0.1** |
| **OECD Asia** | **7.9** | **8.2** | **7.9** | **7.8** | **7.8** | **7.8** | **7.8** | **-0.2** |
| Japan | 4.4 | 4.7 | 4.0 | 3.9 | 3.8 | 3.7 | 3.6 | -0.9 |
| South Korea | 2.3 | 2.3 | 2.5 | 2.5 | 2.5 | 2.6 | 2.7 | 0.5 |
| Australia and New Zealand | 1.2 | 1.2 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 0.8 |
| **Total OECD** | **46.0** | **45.5** | **46.8** | **46.7** | **46.9** | **47.5** | **48.4** | **0.2** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **5.3** | **5.3** | **5.9** | **6.2** | **6.2** | **6.2** | **6.1** | **0.6** |
| Russia | 3.4 | 3.4 | 3.7 | 3.8 | 3.8 | 3.7 | 3.6 | 0.1 |
| Other | 1.9 | 1.8 | 2.2 | 2.4 | 2.5 | 2.5 | 2.6 | 1.2 |
| **Non-OECD Asia** | **20.5** | **21.5** | **27.2** | **29.8** | **32.5** | **35.4** | **38.3** | **2.1** |
| China | 9.5 | 10.2 | 12.9 | 13.8 | 14.7 | 15.3 | 15.5 | 1.5 |
| India | 3.5 | 3.6 | 4.7 | 5.3 | 6.1 | 7.1 | 8.3 | 3.0 |
| Other | 7.5 | 7.7 | 9.7 | 10.7 | 11.7 | 13.0 | 14.4 | 2.3 |
| **Middle East** | **7.4** | **7.7** | **10.3** | **10.6** | **11.4** | **12.4** | **13.2** | **1.9** |
| **Africa** | **3.4** | **3.6** | **4.6** | **5.2** | **5.6** | **6.2** | **7.0** | **2.4** |
| **Non-OECD Americas** | **6.4** | **6.7** | **7.8** | **8.2** | **8.7** | **9.2** | **9.8** | **1.4** |
| Brazil | 2.8 | 2.9 | 3.5 | 3.8 | 4.1 | 4.5 | 4.8 | 1.8 |
| Other | 3.6 | 3.8 | 4.2 | 4.4 | 4.6 | 4.7 | 5.0 | 1.0 |
| **Total Non-OECD** | **43.1** | **44.8** | **55.8** | **60.0** | **64.4** | **69.4** | **74.5** | **1.8** |
| **Total World** | **89.1** | **90.3** | **102.6** | **106.7** | **111.4** | **116.9** | **122.8** | **1.1** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **History:** U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies.
**Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run LOWPRICE.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-oil_price_low_2016.02.19_115013.

## Appendix F

# Reference case projections by end-use sector and country grouping

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## Table F1. Total world delivered energy consumption by end-use sector and fuel, 2011–40
(quadrillion Btu)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Sector/fuel | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| **Residential** | | | | | | | | |
| Liquids | 9.1 | 9.2 | 10.0 | 9.8 | 9.5 | 9.3 | 9.0 | -0.1 |
| Natural gas | 19.9 | 19.4 | 22.8 | 24.6 | 26.2 | 27.4 | 28.1 | 1.3 |
| Coal | 4.7 | 4.8 | 4.5 | 4.3 | 4.1 | 4.1 | 4.0 | -0.6 |
| Electricity | 18.0 | 18.4 | 22.5 | 25.5 | 28.6 | 32.0 | 35.8 | 2.4 |
| Renewables | 0.7 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 | 0.3 |
| Total | **52.4** | **53.0** | **61.1** | **65.4** | **69.8** | **74.1** | **78.3** | **1.4** |
| **Commercial** | | | | | | | | |
| Liquids | 3.9 | 3.9 | 4.4 | 4.4 | 4.5 | 4.5 | 4.5 | 0.5 |
| Natural gas | 8.6 | 8.4 | 9.8 | 10.3 | 10.8 | 11.0 | 10.9 | 0.9 |
| Coal | 1.2 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.6 | 0.2 |
| Electricity | 15.2 | 15.4 | 18.6 | 20.8 | 23.1 | 25.6 | 28.1 | 2.2 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 |
| Total | **29.0** | **29.3** | **34.5** | **37.2** | **40.0** | **42.7** | **45.2** | **1.6** |
| **Industrial** | | | | | | | | |
| Liquids | 65.3 | 66.5 | 72.2 | 76.5 | 80.6 | 84.6 | 88.6 | 1.0 |
| Natural gas | 49.1 | 50.7 | 56.2 | 62.0 | 68.0 | 74.5 | 80.4 | 1.7 |
| Coal | 54.5 | 55.7 | 62.0 | 64.3 | 66.0 | 67.5 | 68.7 | 0.7 |
| Electricity | 31.5 | 31.9 | 37.2 | 40.0 | 42.2 | 44.3 | 46.3 | 1.3 |
| Renewables | 16.6 | 17.4 | 18.2 | 19.7 | 21.3 | 23.0 | 25.1 | 1.3 |
| Total | **217.0** | **222.3** | **245.8** | **262.6** | **278.0** | **294.0** | **309.1** | **1.2** |
| **Transportation** | | | | | | | | |
| Liquids | 99.0 | 100.3 | 110.0 | 115.3 | 121.0 | 128.4 | 136.8 | 1.1 |
| Natural gas | 3.3 | 3.3 | 5.0 | 6.6 | 9.3 | 12.3 | 16.1 | 5.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.6 | 0.6 | 0.8 | 1.0 | 1.2 | 1.5 | 2.0 | 4.4 |
| Total | **102.8** | **104.2** | **115.8** | **122.9** | **131.6** | **142.2** | **154.8** | **1.4** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 177.3 | 180.0 | 196.3 | 205.7 | 215.3 | 226.3 | 238.5 | 1.0 |
| Natural gas | 80.9 | 81.8 | 93.9 | 103.6 | 114.3 | 125.3 | 135.4 | 1.8 |
| Coal | 60.4 | 62.0 | 68.0 | 70.1 | 71.6 | 73.1 | 74.3 | 0.6 |
| Electricity | 65.2 | 66.3 | 79.1 | 87.3 | 95.1 | 103.4 | 112.2 | 1.9 |
| Renewables | 17.4 | 18.8 | 19.7 | 21.2 | 22.7 | 24.5 | 26.6 | 1.2 |
| Delivered energy | **401.3** | **408.9** | **456.9** | **487.8** | **519.1** | **552.7** | **587.0** | **1.3** |
| Electricity-related losses | 139.3 | 140.4 | 172.1 | 186.1 | 198.7 | 212.9 | 227.9 | 1.7 |
| Total | **540.5** | **549.3** | **628.9** | **673.9** | **717.7** | **765.6** | **815.0** | **1.4** |
| **Electric power[a]** | | | | | | | | |
| Liquids | 7.8 | 8.4 | 7.3 | 6.1 | 5.5 | 5.2 | 5.0 | -1.8 |
| Natural gas | 40.0 | 41.8 | 44.4 | 51.3 | 58.8 | 67.3 | 76.0 | 2.2 |
| Coal | 91.4 | 91.1 | 100.7 | 103.0 | 102.8 | 103.9 | 105.9 | 0.5 |
| Nuclear | 26.2 | 24.5 | 30.9 | 34.6 | 40.2 | 43.4 | 46.0 | 2.3 |
| Renewables | 43.0 | 45.0 | 67.3 | 77.6 | 85.4 | 94.9 | 104.8 | 3.1 |
| Total | **208.4** | **210.7** | **250.6** | **272.6** | **292.7** | **314.7** | **337.7** | **1.7** |
| **Unspecified sector** | **-3.4** | **-3.6** | **0.3** | **0.4** | **0.7** | **1.3** | **2.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 180.3 | 183.6 | 204.2 | 212.5 | 221.8 | 233.2 | 246.0 | 1.1 |
| Natural gas | 121.6 | 124.2 | 138.3 | 154.8 | 173.1 | 192.5 | 211.4 | 1.9 |
| Coal | 152.0 | 153.3 | 168.6 | 173.2 | 174.4 | 176.9 | 180.2 | 0.6 |
| Nuclear | 26.2 | 24.5 | 30.9 | 34.6 | 40.2 | 43.4 | 46.0 | 2.3 |
| Renewables | 60.4 | 63.8 | 87.0 | 98.8 | 108.1 | 119.5 | 131.4 | 2.6 |
| Total | **540.5** | **549.3** | **628.9** | **673.9** | **717.7** | **765.6** | **815.0** | **1.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F2. Total OECD delivered energy consumption by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 4.1 | 4.0 | 4.1 | 4.0 | 3.9 | 3.7 | 3.6 | -0.3 |
| Natural gas | 11.4 | 11.0 | 12.4 | 12.8 | 13.2 | 13.3 | 13.1 | 0.6 |
| Coal | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | -0.3 |
| Electricity | 10.4 | 10.3 | 11.2 | 11.7 | 12.3 | 13.0 | 13.6 | 1.0 |
| Renewables | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | -0.3 |
| Total | **27.4** | **26.6** | **29.0** | **29.8** | **30.6** | **31.2** | **31.6** | **0.6** |
| **Commercial** | | | | | | | | |
| Liquids | 2.6 | 2.5 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 0.2 |
| Natural gas | 6.8 | 6.6 | 7.6 | 7.8 | 8.0 | 8.1 | 8.0 | 0.7 |
| Coal | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | -0.3 |
| Electricity | 10.5 | 10.5 | 11.9 | 12.8 | 13.8 | 14.8 | 16.0 | 1.5 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 |
| Total | **20.2** | **20.0** | **22.8** | **23.8** | **25.0** | **26.1** | **27.1** | **1.1** |
| **Industrial** | | | | | | | | |
| Liquids | 27.4 | 27.2 | 28.9 | 29.8 | 30.3 | 30.4 | 30.6 | 0.4 |
| Natural gas | 20.8 | 21.0 | 22.7 | 23.4 | 24.2 | 24.9 | 25.7 | 0.7 |
| Coal | 8.7 | 8.5 | 8.7 | 8.8 | 8.9 | 9.0 | 9.0 | 0.2 |
| Electricity | 11.2 | 10.9 | 11.6 | 12.1 | 12.5 | 12.8 | 13.2 | 0.7 |
| Renewables | 5.3 | 5.7 | 5.7 | 5.8 | 5.9 | 5.9 | 6.1 | 0.2 |
| Total | **73.4** | **73.3** | **77.6** | **80.0** | **81.7** | **83.0** | **84.6** | **0.5** |
| **Transportation** | | | | | | | | |
| Liquids | 57.0 | 56.2 | 56.6 | 55.5 | 55.4 | 56.0 | 56.9 | 0.0 |
| Natural gas | 1.0 | 1.0 | 1.2 | 1.4 | 1.8 | 2.2 | 2.9 | 4.0 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 3.5 |
| Total | **58.2** | **57.5** | **58.1** | **57.3** | **57.5** | **58.7** | **60.5** | **0.2** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 91.1 | 90.0 | 92.1 | 91.7 | 91.9 | 92.5 | 93.5 | 0.1 |
| Natural gas | 40.0 | 39.6 | 43.9 | 45.5 | 47.2 | 48.6 | 49.7 | 0.8 |
| Coal | 9.6 | 9.5 | 9.7 | 9.8 | 9.9 | 9.9 | 10.0 | 0.2 |
| Electricity | 32.3 | 31.9 | 35.0 | 37.0 | 38.9 | 41.1 | 43.5 | 1.1 |
| Renewables | 6.1 | 6.4 | 6.4 | 6.5 | 6.6 | 6.6 | 6.7 | 0.2 |
| Delivered energy | **179.2** | **177.4** | **187.1** | **190.5** | **194.5** | **198.7** | **203.4** | **0.5** |
| Electricity-related losses | 62.8 | 61.0 | 66.8 | 70.1 | 72.8 | 75.6 | 78.7 | 0.9 |
| Total | **242.0** | **238.4** | **253.9** | **260.6** | **267.2** | **274.3** | **282.1** | **0.6** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 1.7 | 1.9 | 1.3 | 0.9 | 0.9 | 0.8 | 0.8 | -3.0 |
| Natural gas | 19.1 | 19.7 | 19.2 | 21.6 | 24.5 | 27.3 | 30.8 | 1.6 |
| Coal | 33.9 | 32.2 | 34.0 | 34.2 | 33.4 | 33.0 | 32.8 | 0.1 |
| Nuclear | 21.2 | 19.3 | 21.3 | 22.1 | 23.0 | 23.1 | 22.5 | 0.6 |
| Renewables | 20.1 | 20.6 | 29.0 | 31.4 | 33.3 | 35.9 | 38.8 | 2.3 |
| Total | **96.1** | **93.8** | **104.9** | **110.2** | **115.0** | **120.1** | **125.8** | **1.1** |
| **Unspecified sector** | **-0.8** | **-0.7** | **-3.4** | **-3.5** | **-3.6** | **-3.8** | **-3.9** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 91.7 | 90.9 | 90.4 | 89.5 | 89.5 | 90.0 | 90.8 | 0.0 |
| Natural gas | 59.2 | 59.5 | 63.1 | 67.1 | 71.7 | 75.9 | 80.5 | 1.1 |
| Coal | 43.6 | 41.8 | 43.7 | 44.0 | 43.3 | 42.9 | 42.7 | 0.1 |
| Nuclear | 21.2 | 19.3 | 21.3 | 22.1 | 23.0 | 23.1 | 22.5 | 0.6 |
| Renewables | 26.3 | 27.0 | 35.5 | 37.9 | 39.8 | 42.5 | 45.5 | 1.9 |
| Total | **242.0** | **238.4** | **253.9** | **260.6** | **267.2** | **274.3** | **282.1** | **0.6** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table F3. Delivered energy consumption in the United States by end-use sector and fuel, 2011–40**
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 1.1 | 0.9 | 0.7 | 0.7 | 0.6 | 0.5 | 0.5 | -2.1 |
| Natural gas | 4.8 | 4.3 | 4.6 | 4.5 | 4.5 | 4.4 | 4.3 | 0.1 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 4.9 | 4.7 | 4.9 | 4.9 | 5.1 | 5.2 | 5.4 | 0.5 |
| Renewables | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.8 |
| Total | **11.3** | **10.3** | **10.6** | **10.5** | **10.6** | **10.6** | **10.6** | **0.1** |
| **Commercial** | | | | | | | | |
| Liquids | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.0 |
| Natural gas | 3.2 | 3.0 | 3.3 | 3.3 | 3.4 | 3.6 | 3.7 | 0.8 |
| Coal | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Electricity | 4.5 | 4.5 | 4.8 | 5.0 | 5.2 | 5.4 | 5.7 | 0.8 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 |
| Total | **8.6** | **8.2** | **8.9** | **9.1** | **9.4** | **9.7** | **10.1** | **0.7** |
| **Industrial** | | | | | | | | |
| Liquids | 8.0 | 8.1 | 9.6 | 10.2 | 10.4 | 10.5 | 10.6 | 1.0 |
| Natural gas | 8.5 | 8.8 | 10.2 | 10.4 | 10.7 | 10.9 | 11.2 | 0.9 |
| Coal | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | -0.1 |
| Electricity | 3.4 | 3.4 | 3.7 | 4.0 | 4.0 | 4.1 | 4.1 | 0.7 |
| Renewables | 2.2 | 2.2 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 | 0.4 |
| Total | **23.6** | **24.0** | **27.4** | **28.6** | **29.1** | **29.3** | **29.8** | **0.8** |
| **Transportation** | | | | | | | | |
| Liquids | 25.9 | 25.3 | 26.3 | 25.6 | 25.0 | 24.9 | 24.8 | -0.1 |
| Natural gas | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.3 | 1.7 | 2.7 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 3.4 |
| Total | **26.7** | **26.2** | **27.2** | **26.6** | **26.2** | **26.2** | **26.5** | **0.0** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 35.6 | 34.9 | 36.9 | 36.7 | 36.3 | 36.1 | 36.0 | 0.1 |
| Natural gas | 17.3 | 16.8 | 19.0 | 19.3 | 19.8 | 20.2 | 20.9 | 0.8 |
| Coal | 1.6 | 1.5 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 0.0 |
| Electricity | 12.8 | 12.6 | 13.4 | 13.9 | 14.3 | 14.7 | 15.3 | 0.7 |
| Renewables | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 0.2 |
| Delivered energy | **70.1** | **68.7** | **73.8** | **74.4** | **74.9** | **75.4** | **76.6** | **0.4** |
| Electricity-related losses | 26.7 | 25.7 | 27.0 | 27.6 | 28.0 | 28.5 | 29.1 | 0.4 |
| Total | **96.8** | **94.4** | **100.8** | **102.0** | **102.9** | **103.8** | **105.7** | **0.4** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.9 |
| Natural gas | 7.7 | 9.3 | 7.8 | 8.3 | 9.0 | 9.4 | 9.6 | 0.1 |
| Coal | 18.0 | 15.8 | 17.6 | 17.8 | 17.6 | 17.5 | 17.5 | 0.4 |
| Nuclear | 8.3 | 8.1 | 8.4 | 8.5 | 8.5 | 8.5 | 8.7 | 0.3 |
| Renewables | 5.1 | 4.9 | 6.5 | 6.8 | 7.1 | 7.6 | 8.3 | 1.9 |
| Total | **39.5** | **38.3** | **40.4** | **41.5** | **42.4** | **43.2** | **44.4** | **0.5** |
| **Unspecified sector** | **0.0** | **0.0** | **-0.3** | **-0.4** | **-0.4** | **-0.4** | **-0.4** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 35.9 | 35.2 | 37.1 | 36.9 | 36.5 | 36.3 | 36.2 | 0.1 |
| Natural gas | 25.0 | 26.1 | 26.8 | 27.6 | 28.8 | 29.6 | 30.5 | 0.6 |
| Coal | 19.6 | 17.3 | 19.2 | 19.3 | 19.2 | 19.0 | 19.0 | 0.3 |
| Nuclear | 8.3 | 8.1 | 8.4 | 8.5 | 8.5 | 8.5 | 8.7 | 0.3 |
| Renewables | 7.9 | 7.7 | 9.3 | 9.7 | 9.9 | 10.4 | 11.3 | 1.4 |
| Total | **96.8** | **94.4** | **100.8** | **102.0** | **102.9** | **103.8** | **105.7** | **0.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.
Sources: EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo.

## Table F4. Delivered energy consumption in Canada by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| Natural gas | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.2 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.8 | 1.2 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **1.3** | **1.3** | **1.3** | **1.4** | **1.4** | **1.5** | **1.5** | **0.7** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| Natural gas | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | -1.2 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.5 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 2.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **1.2** | **1.1** | **1.2** | **1.3** | **1.4** | **1.5** | **1.6** | **1.4** |
| **Industrial** | | | | | | | | |
| Liquids | 1.9 | 1.9 | 1.8 | 1.8 | 1.9 | 1.9 | 2.0 | 0.2 |
| Natural gas | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.7 | 2.8 | 0.9 |
| Coal | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1.3 |
| Electricity | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.9 | 1.0 |
| Renewables | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.3 |
| Total | **5.3** | **5.4** | **5.3** | **5.5** | **5.8** | **6.1** | **6.3** | **0.6** |
| **Transportation** | | | | | | | | |
| Liquids | 2.4 | 2.4 | 2.3 | 2.2 | 2.2 | 2.3 | 2.4 | -0.1 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 2.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 |
| Total | **2.5** | **2.5** | **2.4** | **2.3** | **2.3** | **2.4** | **2.5** | **0.0** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 4.5 | 4.5 | 4.3 | 4.3 | 4.3 | 4.4 | 4.6 | 0.0 |
| Natural gas | 3.4 | 3.4 | 3.3 | 3.4 | 3.6 | 3.8 | 4.0 | 0.6 |
| Coal | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1.3 |
| Electricity | 1.8 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.9 | 1.7 |
| Renewables | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.3 |
| Delivered energy | **10.3** | **10.3** | **10.2** | **10.5** | **10.9** | **11.5** | **12.0** | **0.6** |
| Electricity-related losses | 4.2 | 4.2 | 4.9 | 5.1 | 5.3 | 5.6 | 6.0 | 1.3 |
| Total | **14.5** | **14.5** | **15.1** | **15.6** | **16.3** | **17.1** | **18.1** | **0.8** |
| **Electric power[a]** | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.9 |
| Natural gas | 0.5 | 0.5 | 0.7 | 1.0 | 1.3 | 1.6 | 1.9 | 4.9 |
| Coal | 0.6 | 0.6 | 0.4 | 0.4 | 0.2 | 0.2 | 0.1 | -5.2 |
| Nuclear | 1.0 | 1.0 | 1.0 | 0.8 | 0.8 | 0.8 | 0.7 | -1.2 |
| Renewables | 3.9 | 3.8 | 4.4 | 4.7 | 5.1 | 5.4 | 5.9 | 1.6 |
| Total | **6.0** | **5.9** | **6.6** | **7.0** | **7.4** | **8.0** | **8.6** | **1.4** |
| **Unspecified sector** | **0.1** | **0.1** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 4.6 | 4.7 | 4.7 | 4.6 | 4.6 | 4.7 | 4.9 | 0.2 |
| Natural gas | 3.9 | 3.9 | 4.0 | 4.4 | 4.9 | 5.4 | 5.8 | 1.5 |
| Coal | 0.7 | 0.7 | 0.6 | 0.6 | 0.4 | 0.4 | 0.4 | -2.5 |
| Nuclear | 1.0 | 1.0 | 1.0 | 0.8 | 0.8 | 0.8 | 0.7 | -1.2 |
| Renewables | 4.3 | 4.2 | 4.8 | 5.1 | 5.5 | 5.8 | 6.3 | 1.4 |
| Total | **14.5** | **14.5** | **15.1** | **15.6** | **16.3** | **17.1** | **18.1** | **0.8** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F5. Delivered energy consumption in Mexico and Chile by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.0 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 3.7 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **0.6** | **0.7** | **0.8** | **0.8** | **0.9** | **1.0** | **1.1** | **1.9** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 3.0 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 4.3 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **0.2** | **0.2** | **0.3** | **0.4** | **0.5** | **0.5** | **0.6** | **3.6** |
| **Industrial** | | | | | | | | |
| Liquids | 1.5 | 1.5 | 1.5 | 1.5 | 1.7 | 1.8 | 2.0 | 1.1 |
| Natural gas | 1.6 | 1.6 | 1.6 | 1.6 | 1.8 | 1.9 | 2.0 | 0.9 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 1.7 |
| Electricity | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 0.9 | 1.0 | 1.7 |
| Renewables | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 1.7 |
| Total | **4.1** | **4.1** | **4.2** | **4.4** | **4.8** | **5.2** | **5.7** | **1.2** |
| **Transportation** | | | | | | | | |
| Liquids | 2.7 | 2.8 | 2.9 | 3.0 | 3.2 | 3.5 | 3.8 | 1.1 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 21.3 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 |
| Total | **2.7** | **2.8** | **2.9** | **3.0** | **3.2** | **3.6** | **4.0** | **1.2** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 4.7 | 4.7 | 4.9 | 5.1 | 5.4 | 5.8 | 6.3 | 1.1 |
| Natural gas | 1.7 | 1.7 | 1.7 | 1.7 | 1.9 | 2.1 | 2.3 | 1.2 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 1.6 |
| Electricity | 1.0 | 1.0 | 1.2 | 1.3 | 1.6 | 1.8 | 2.1 | 2.6 |
| Renewables | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 1.7 |
| Delivered energy | **7.7** | **7.8** | **8.3** | **8.7** | **9.4** | **10.3** | **11.4** | **1.4** |
| Electricity-related losses | 1.6 | 1.4 | 1.5 | 1.8 | 2.2 | 2.5 | 2.9 | 2.7 |
| Total | **9.3** | **9.2** | **9.8** | **10.5** | **11.6** | **12.8** | **14.3** | **1.6** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.4 | 0.5 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | -5.6 |
| Natural gas | 1.3 | 1.1 | 1.3 | 1.7 | 2.0 | 2.4 | 2.8 | 3.3 |
| Coal | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | -0.2 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 4.2 |
| Renewables | 0.7 | 0.7 | 1.1 | 1.4 | 1.6 | 1.9 | 2.2 | 4.4 |
| Total | **3.0** | **2.8** | **3.3** | **3.8** | **4.4** | **5.0** | **5.8** | **2.7** |
| **Unspecified sector** | **-0.4** | **-0.4** | **-0.6** | **-0.6** | **-0.7** | **-0.7** | **-0.8** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 4.8 | 4.8 | 4.7 | 4.6 | 4.8 | 5.2 | 5.6 | 0.6 |
| Natural gas | 2.9 | 2.8 | 3.0 | 3.5 | 3.9 | 4.5 | 5.1 | 2.2 |
| Coal | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.3 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 4.2 |
| Renewables | 0.9 | 1.0 | 1.5 | 1.8 | 2.1 | 2.4 | 2.7 | 3.7 |
| Total | **9.3** | **9.2** | **9.8** | **10.5** | **11.6** | **12.8** | **14.3** | **1.6** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

# Table F6. Delivered energy consumption in OECD Europe by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| Residential | | | | | | | | |
| Liquids | 1.9 | 1.8 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 0.1 |
| Natural gas | 4.9 | 5.2 | 6.0 | 6.4 | 6.7 | 6.9 | 6.8 | 1.0 |
| Coal | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | -0.4 |
| Electricity | 3.1 | 3.2 | 3.6 | 3.9 | 4.2 | 4.4 | 4.7 | 1.4 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.8 |
| **Total** | **10.8** | **11.0** | **12.5** | **13.1** | **13.6** | **14.0** | **14.2** | **0.9** |
| Commercial | | | | | | | | |
| Liquids | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.0 |
| Natural gas | 2.1 | 2.2 | 2.7 | 2.8 | 3.0 | 3.0 | 2.8 | 0.9 |
| Coal | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | -0.5 |
| Electricity | 3.2 | 3.3 | 3.8 | 4.1 | 4.5 | 4.9 | 5.4 | 1.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| **Total** | **6.2** | **6.5** | **7.5** | **8.0** | **8.5** | **8.9** | **9.2** | **1.3** |
| Industrial | | | | | | | | |
| Liquids | 9.1 | 8.7 | 8.7 | 8.8 | 9.0 | 9.0 | 9.1 | 0.2 |
| Natural gas | 6.7 | 6.5 | 6.5 | 6.7 | 6.8 | 6.9 | 6.9 | 0.2 |
| Coal | 3.2 | 3.1 | 3.0 | 3.1 | 3.1 | 3.1 | 3.2 | 0.1 |
| Electricity | 4.4 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 | 4.6 | 0.3 |
| Renewables | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | -0.1 |
| **Total** | **25.1** | **24.4** | **24.4** | **24.9** | **25.3** | **25.5** | **25.6** | **0.2** |
| Transportation | | | | | | | | |
| Liquids | 18.8 | 18.4 | 18.3 | 17.9 | 18.1 | 18.4 | 18.8 | 0.1 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 8.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 4.0 |
| **Total** | **19.0** | **18.6** | **18.5** | **18.2** | **18.6** | **19.1** | **19.8** | **0.2** |
| All end-use sectors | | | | | | | | |
| Liquids | 30.5 | 29.7 | 29.8 | 29.6 | 29.8 | 30.1 | 30.5 | 0.1 |
| Natural gas | 13.8 | 13.9 | 15.3 | 16.1 | 16.8 | 17.2 | 17.2 | 0.8 |
| Coal | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 0.0 |
| Electricity | 10.8 | 10.9 | 11.8 | 12.6 | 13.3 | 14.1 | 15.1 | 1.2 |
| Renewables | 2.0 | 2.1 | 2.0 | 2.0 | 2.1 | 2.0 | 2.0 | -0.1 |
| Delivered energy | **61.1** | **60.6** | **62.9** | **64.2** | **66.0** | **67.5** | **68.8** | **0.5** |
| Electricity-related losses | 20.8 | 20.8 | 22.0 | 23.2 | 24.3 | 25.6 | 26.7 | 0.9 |
| **Total** | **82.0** | **81.4** | **84.9** | **87.5** | **90.3** | **93.1** | **95.5** | **0.6** |
| Electric power[a] | | | | | | | | |
| Liquids | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.8 |
| Natural gas | 5.4 | 4.3 | 4.4 | 5.0 | 6.1 | 7.1 | 8.9 | 2.6 |
| Coal | 8.9 | 9.4 | 9.2 | 9.4 | 9.1 | 8.8 | 8.6 | -0.3 |
| Nuclear | 8.8 | 8.6 | 7.9 | 8.3 | 8.8 | 9.0 | 8.5 | 0.0 |
| Renewables | 8.7 | 9.5 | 13.7 | 14.6 | 15.2 | 16.4 | 17.5 | 2.2 |
| **Total** | **32.1** | **32.2** | **35.7** | **37.8** | **39.6** | **41.8** | **43.9** | **1.1** |
| Unspecified sector | **-0.3** | **-0.5** | **-1.9** | **-2.0** | **-2.0** | **-2.1** | **-2.1** | **—** |
| Total energy consumption | | | | | | | | |
| Liquids | 30.4 | 29.6 | 28.3 | 28.0 | 28.2 | 28.5 | 28.8 | -0.1 |
| Natural gas | 19.2 | 18.3 | 19.7 | 21.1 | 23.0 | 24.3 | 26.1 | 1.3 |
| Coal | 12.9 | 13.4 | 13.2 | 13.3 | 13.1 | 12.8 | 12.6 | -0.2 |
| Nuclear | 8.8 | 8.6 | 7.9 | 8.3 | 8.8 | 9.0 | 8.5 | 0.0 |
| Renewables | 10.7 | 11.5 | 15.7 | 16.7 | 17.3 | 18.5 | 19.6 | 1.9 |
| **Total** | **82.0** | **81.4** | **84.9** | **87.5** | **90.3** | **93.1** | **95.5** | **0.6** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table F7. Delivered energy consumption in Japan by end-use sector and fuel, 2011–40**
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.6 | 0.6 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.0 |
| Natural gas | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 1.2 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 0.5 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| **Total** | **2.1** | **2.1** | **2.3** | **2.4** | **2.4** | **2.4** | **2.4** | **0.4** |
| **Commercial** | | | | | | | | |
| Liquids | 0.7 | 0.8 | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.0 |
| Natural gas | 0.8 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.2 |
| Electricity | 1.3 | 1.3 | 1.4 | 1.5 | 1.6 | 1.6 | 1.6 | 0.9 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| **Total** | **2.9** | **2.8** | **3.3** | **3.4** | **3.4** | **3.5** | **3.4** | **0.6** |
| **Industrial** | | | | | | | | |
| Liquids | 3.7 | 3.9 | 3.9 | 3.8 | 3.7 | 3.6 | 3.3 | -0.6 |
| Natural gas | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.3 |
| Coal | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.0 | -0.5 |
| Electricity | 0.8 | 0.7 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | -0.3 |
| Renewables | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.3 |
| **Total** | **7.8** | **8.0** | **8.1** | **8.1** | **7.9** | **7.6** | **7.0** | **-0.4** |
| **Transportation** | | | | | | | | |
| Liquids | 3.9 | 3.9 | 3.3 | 3.1 | 3.1 | 3.1 | 3.1 | -0.8 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 3.0 |
| **Total** | **4.0** | **3.9** | **3.4** | **3.2** | **3.2** | **3.2** | **3.3** | **-0.7** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 8.9 | 9.1 | 8.7 | 8.5 | 8.3 | 8.1 | 7.7 | -0.6 |
| Natural gas | 1.8 | 1.8 | 2.2 | 2.3 | 2.3 | 2.3 | 2.1 | 0.6 |
| Coal | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.2 | 2.0 | -0.5 |
| Electricity | 3.4 | 3.1 | 3.4 | 3.6 | 3.6 | 3.7 | 3.7 | 0.6 |
| Renewables | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.2 |
| Delivered energy | **16.8** | **16.8** | **17.1** | **17.1** | **16.9** | **16.7** | **16.0** | **-0.2** |
| Electricity-related losses | 4.4 | 3.9 | 4.8 | 5.3 | 5.4 | 5.5 | 5.4 | 1.2 |
| **Total** | **21.2** | **20.8** | **21.9** | **22.3** | **22.3** | **22.2** | **21.5** | **0.1** |
| **Electric power[a]** | | | | | | | | |
| Liquids | 0.5 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | -11.4 |
| Natural gas | 2.9 | 3.1 | 3.2 | 3.7 | 3.8 | 4.0 | 4.2 | 1.1 |
| Coal | 2.1 | 2.3 | 2.2 | 2.1 | 2.0 | 2.0 | 1.9 | -0.6 |
| Nuclear | 1.6 | 0.2 | 1.7 | 1.9 | 1.8 | 1.8 | 1.5 | 8.0 |
| Renewables | 1.1 | 1.2 | 1.8 | 2.1 | 2.3 | 2.3 | 2.4 | 2.5 |
| **Total** | **8.2** | **7.3** | **9.2** | **9.7** | **10.0** | **10.1** | **10.0** | **1.1** |
| **Unspecified sector** | **-0.4** | **-0.2** | **-1.0** | **-0.9** | **-0.9** | **-0.9** | **-0.8** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 9.0 | 9.5 | 7.9 | 7.6 | 7.4 | 7.2 | 6.9 | -1.1 |
| Natural gas | 4.7 | 4.9 | 5.4 | 6.0 | 6.1 | 6.3 | 6.3 | 0.9 |
| Coal | 4.3 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.0 | -0.5 |
| Nuclear | 1.6 | 0.2 | 1.7 | 1.9 | 1.8 | 1.8 | 1.5 | 8.0 |
| Renewables | 1.6 | 1.6 | 2.3 | 2.5 | 2.7 | 2.8 | 2.7 | 2.0 |
| **Total** | **21.2** | **20.8** | **21.9** | **22.3** | **22.3** | **22.2** | **21.5** | **0.1** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F8. Delivered energy consumption in South Korea by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 |
| Natural gas | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 1.2 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| Electricity | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 1.6 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| Total | **0.8** | **0.8** | **1.0** | **1.0** | **1.1** | **1.1** | **1.1** | **1.1** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 |
| Natural gas | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.5 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 2.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **0.8** | **0.8** | **1.1** | **1.2** | **1.3** | **1.4** | **1.5** | **2.1** |
| **Industrial** | | | | | | | | |
| Liquids | 2.4 | 2.4 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 0.6 |
| Natural gas | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 1.6 |
| Coal | 1.2 | 1.1 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.5 |
| Electricity | 0.9 | 0.9 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Total | **4.9** | **5.0** | **5.6** | **5.9** | **6.1** | **6.3** | **6.6** | **1.0** |
| **Transportation** | | | | | | | | |
| Liquids | 1.5 | 1.6 | 1.7 | 1.7 | 1.7 | 1.8 | 1.9 | 0.7 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 7.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 |
| Total | **1.6** | **1.6** | **1.7** | **1.7** | **1.8** | **1.9** | **2.0** | **0.8** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 4.2 | 4.3 | 4.7 | 4.7 | 4.8 | 4.9 | 5.0 | 0.6 |
| Natural gas | 0.9 | 1.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | 1.5 |
| Coal | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.5 |
| Electricity | 1.6 | 1.7 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 1.9 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Delivered energy | **8.1** | **8.2** | **9.4** | **9.8** | **10.2** | **10.7** | **11.2** | **1.1** |
| Electricity-related losses | 3.2 | 3.2 | 4.5 | 4.9 | 5.2 | 5.4 | 5.7 | 2.0 |
| Total | **11.3** | **11.4** | **13.9** | **14.7** | **15.4** | **16.1** | **16.9** | **1.4** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | -1.0 |
| Natural gas | 0.9 | 0.9 | 1.2 | 1.1 | 1.3 | 1.5 | 1.8 | 2.4 |
| Coal | 2.0 | 1.9 | 2.4 | 2.3 | 2.3 | 2.4 | 2.5 | 1.0 |
| Nuclear | 1.5 | 1.4 | 2.1 | 2.6 | 2.8 | 2.8 | 2.8 | 2.5 |
| Renewables | 0.1 | 0.1 | 0.6 | 0.7 | 0.9 | 0.9 | 1.0 | 10.2 |
| Total | **4.5** | **4.5** | **6.4** | **6.9** | **7.4** | **7.9** | **8.3** | **2.2** |
| **Unspecified sector** | **0.3** | **0.4** | **0.2** | **0.1** | **0.1** | **0.1** | **0.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 4.6 | 4.8 | 5.0 | 5.0 | 5.0 | 5.2 | 5.3 | 0.4 |
| Natural gas | 1.8 | 2.0 | 2.4 | 2.5 | 2.6 | 3.0 | 3.3 | 1.9 |
| Coal | 3.2 | 3.0 | 3.7 | 3.8 | 3.8 | 4.0 | 4.3 | 1.2 |
| Nuclear | 1.5 | 1.4 | 2.1 | 2.6 | 2.8 | 2.8 | 2.8 | 2.5 |
| Renewables | 0.2 | 0.2 | 0.7 | 0.8 | 1.0 | 1.1 | 1.2 | 7.1 |
| Total | **11.3** | **11.4** | **13.9** | **14.7** | **15.4** | **16.1** | **16.9** | **1.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F9. Delivered energy consumption in Australia/New Zealand by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Natural gas | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1.3 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 2.0 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **0.4** | **0.4** | **0.5** | **0.6** | **0.6** | **0.7** | **0.7** | **1.7** |
| **Commercial** | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.3 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 |
| Electricity | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 3.5 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **0.3** | **0.3** | **0.4** | **0.5** | **0.6** | **0.6** | **0.7** | **2.9** |
| **Industrial** | | | | | | | | |
| Liquids | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.3 |
| Natural gas | 1.0 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.4 | 1.8 |
| Coal | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.5 |
| Electricity | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.6 | 1.6 |
| Renewables | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.8 |
| Total | **2.5** | **2.5** | **2.5** | **2.6** | **2.8** | **3.0** | **3.4** | **1.1** |
| **Transportation** | | | | | | | | |
| Liquids | 1.8 | 1.8 | 2.0 | 2.1 | 2.1 | 2.2 | 2.3 | 0.9 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 6.7 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 |
| Total | **1.8** | **1.9** | **2.0** | **2.1** | **2.2** | **2.3** | **2.4** | **1.0** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.3 | 0.7 |
| Natural gas | 1.2 | 1.1 | 1.2 | 1.3 | 1.4 | 1.6 | 1.8 | 1.8 |
| Coal | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.5 |
| Electricity | 0.9 | 0.9 | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2.3 |
| Renewables | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.8 |
| Delivered energy | **5.1** | **5.1** | **5.5** | **5.8** | **6.1** | **6.6** | **7.3** | **1.3** |
| Electricity-related losses | 1.8 | 1.7 | 2.1 | 2.2 | 2.4 | 2.6 | 2.9 | 1.8 |
| Total | **6.9** | **6.8** | **7.6** | **8.1** | **8.5** | **9.2** | **10.1** | **1.4** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Natural gas | 0.4 | 0.4 | 0.5 | 0.8 | 1.0 | 1.2 | 1.6 | 4.6 |
| Coal | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | -0.5 |
| Nuclear | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Renewables | 0.6 | 0.5 | 1.0 | 1.0 | 1.2 | 1.3 | 1.5 | 3.9 |
| Total | **2.9** | **2.8** | **3.3** | **3.5** | **3.8** | **4.2** | **4.7** | **1.8** |
| **Unspecified sector** | **-0.1** | **-0.2** | **-0.1** | **-0.1** | **-0.1** | **-0.1** | **-0.2** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 2.4 | 2.5 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 0.8 |
| Natural gas | 1.6 | 1.5 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 2.9 |
| Coal | 2.1 | 2.1 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | -0.4 |
| Nuclear | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Renewables | 0.7 | 0.7 | 1.2 | 1.2 | 1.4 | 1.5 | 1.8 | 3.2 |
| Total | **6.9** | **6.8** | **7.6** | **8.1** | **8.5** | **9.2** | **10.1** | **1.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F10. Total non-OECD delivered energy consumption by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 5.0 | 5.2 | 5.9 | 5.8 | 5.7 | 5.5 | 5.4 | 0.1 |
| Natural gas | 8.6 | 8.4 | 10.4 | 11.8 | 13.0 | 14.1 | 14.9 | 2.1 |
| Coal | 3.9 | 4.1 | 3.8 | 3.6 | 3.5 | 3.4 | 3.4 | -0.7 |
| Electricity | 7.6 | 8.1 | 11.3 | 13.8 | 16.3 | 19.0 | 22.2 | 3.7 |
| Renewables | 0.0 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 |
| Total | **25.0** | **26.4** | **32.1** | **35.7** | **39.2** | **42.9** | **46.7** | **2.1** |
| **Commercial** | | | | | | | | |
| Liquids | 1.3 | 1.4 | 1.6 | 1.7 | 1.7 | 1.8 | 1.8 | 0.9 |
| Natural gas | 1.7 | 1.8 | 2.3 | 2.5 | 2.8 | 2.9 | 2.9 | 1.7 |
| Coal | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 0.4 |
| Electricity | 4.7 | 4.9 | 6.7 | 8.0 | 9.3 | 10.7 | 12.1 | 3.3 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **8.8** | **9.3** | **11.7** | **13.4** | **15.0** | **16.6** | **18.1** | **2.4** |
| **Industrial** | | | | | | | | |
| Liquids | 38.0 | 39.3 | 43.3 | 46.7 | 50.3 | 54.2 | 57.9 | 1.4 |
| Natural gas | 28.2 | 29.7 | 33.6 | 38.6 | 43.8 | 49.6 | 54.7 | 2.2 |
| Coal | 45.9 | 47.3 | 53.4 | 55.5 | 57.1 | 58.6 | 59.7 | 0.8 |
| Electricity | 20.4 | 21.0 | 25.5 | 27.9 | 29.7 | 31.5 | 33.1 | 1.6 |
| Renewables | 11.2 | 11.8 | 12.5 | 13.9 | 15.4 | 17.1 | 19.0 | 1.7 |
| Total | **143.6** | **149.0** | **168.3** | **182.6** | **196.3** | **211.0** | **224.5** | **1.5** |
| **Transportation** | | | | | | | | |
| Liquids | 42.0 | 44.1 | 53.3 | 59.7 | 65.7 | 72.3 | 79.9 | 2.1 |
| Natural gas | 2.4 | 2.3 | 3.8 | 5.2 | 7.6 | 10.1 | 13.2 | 6.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.3 | 0.3 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | 5.0 |
| Total | **44.6** | **46.8** | **57.6** | **65.7** | **74.1** | **83.5** | **94.4** | **2.5** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 86.2 | 90.0 | 104.2 | 113.9 | 123.4 | 133.8 | 145.0 | 1.7 |
| Natural gas | 40.9 | 42.2 | 50.0 | 58.1 | 67.1 | 76.7 | 85.7 | 2.6 |
| Coal | 50.8 | 52.5 | 58.3 | 60.3 | 61.8 | 63.2 | 64.3 | 0.7 |
| Electricity | 32.9 | 34.4 | 44.1 | 50.3 | 56.1 | 62.4 | 68.7 | 2.5 |
| Renewables | 11.3 | 12.4 | 13.2 | 14.7 | 16.2 | 17.9 | 19.9 | 1.7 |
| Delivered energy | **222.1** | **231.5** | **269.7** | **297.3** | **324.6** | **354.0** | **383.6** | **1.8** |
| Electricity-related losses | 76.5 | 79.3 | 105.3 | 116.0 | 125.9 | 137.3 | 149.2 | 2.3 |
| Total | **298.6** | **310.8** | **375.0** | **413.3** | **450.5** | **491.2** | **532.8** | **1.9** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 6.1 | 6.4 | 6.0 | 5.2 | 4.6 | 4.4 | 4.2 | -1.5 |
| Natural gas | 20.9 | 22.1 | 25.2 | 29.7 | 34.3 | 39.9 | 45.1 | 2.6 |
| Coal | 57.5 | 58.9 | 66.6 | 68.9 | 69.4 | 70.9 | 73.2 | 0.8 |
| Nuclear | 5.0 | 5.2 | 9.6 | 12.4 | 17.2 | 20.3 | 23.4 | 5.5 |
| Renewables | 22.8 | 24.3 | 38.3 | 46.3 | 52.1 | 59.1 | 66.0 | 3.6 |
| Total | **112.3** | **116.9** | **145.7** | **162.4** | **177.7** | **194.6** | **211.9** | **2.1** |
| **Unspecified sector** | **-2.6** | **-2.9** | **3.7** | **3.9** | **4.3** | **5.0** | **6.0** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 88.6 | 92.6 | 113.8 | 123.0 | 132.3 | 143.3 | 155.3 | 1.9 |
| Natural gas | 62.4 | 64.8 | 75.2 | 87.8 | 101.4 | 116.6 | 130.9 | 2.5 |
| Coal | 108.4 | 111.5 | 124.9 | 129.2 | 131.2 | 134.0 | 137.5 | 0.8 |
| Nuclear | 5.0 | 5.2 | 9.6 | 12.4 | 17.2 | 20.3 | 23.4 | 5.5 |
| Renewables | 34.1 | 36.8 | 51.5 | 60.9 | 68.3 | 77.0 | 85.8 | 3.1 |
| Total | **298.6** | **310.8** | **375.0** | **413.3** | **450.5** | **491.2** | **532.8** | **1.9** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F11. Delivered energy consumption in Russia by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | -0.2 |
| Natural gas | 2.9 | 2.6 | 2.9 | 3.0 | 3.0 | 3.0 | 2.9 | 0.4 |
| Coal | 0.3 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | -0.6 |
| Electricity | 0.5 | 0.5 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 2.4 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **4.0** | **3.8** | **4.2** | **4.4** | **4.4** | **4.5** | **4.5** | **0.6** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Natural gas | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.2 |
| Coal | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.2 |
| Electricity | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 0.8 | 0.9 | 1.7 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **1.2** | **1.3** | **1.4** | **1.5** | **1.5** | **1.6** | **1.6** | **0.8** |
| **Industrial** | | | | | | | | |
| Liquids | 3.6 | 3.7 | 3.3 | 3.4 | 3.3 | 3.3 | 3.1 | -0.6 |
| Natural gas | 5.1 | 5.5 | 5.1 | 5.3 | 5.4 | 5.4 | 4.9 | -0.4 |
| Coal | 2.1 | 2.4 | 2.3 | 2.4 | 2.4 | 2.4 | 2.2 | -0.3 |
| Electricity | 1.7 | 1.7 | 1.6 | 1.6 | 1.7 | 1.7 | 1.6 | -0.3 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -1.2 |
| Total | **12.6** | **13.4** | **12.4** | **12.8** | **12.9** | **12.8** | **11.8** | **-0.4** |
| **Transportation** | | | | | | | | |
| Liquids | 3.2 | 3.4 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 0.2 |
| Natural gas | 1.1 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Total | **4.3** | **4.4** | **4.6** | **4.9** | **5.1** | **5.3** | **5.5** | **0.8** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 7.3 | 7.6 | 7.4 | 7.5 | 7.5 | 7.4 | 7.2 | -0.2 |
| Natural gas | 9.4 | 9.5 | 9.5 | 10.0 | 10.2 | 10.4 | 10.1 | 0.2 |
| Coal | 2.6 | 3.0 | 2.8 | 2.9 | 2.9 | 2.9 | 2.7 | -0.3 |
| Electricity | 2.7 | 2.8 | 2.8 | 3.0 | 3.2 | 3.4 | 3.4 | 0.7 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -1.2 |
| Delivered energy | **22.2** | **22.9** | **22.6** | **23.6** | **23.9** | **24.3** | **23.4** | **0.1** |
| Electricity-related losses | 8.7 | 9.1 | 10.6 | 11.1 | 11.2 | 11.2 | 11.1 | 0.7 |
| Total | **30.9** | **32.1** | **33.2** | **34.7** | **35.1** | **35.5** | **34.5** | **0.3** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.3 | 0.3 | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | -0.2 |
| Natural gas | 6.1 | 6.5 | 6.3 | 6.2 | 6.4 | 6.5 | 6.3 | -0.1 |
| Coal | 2.1 | 2.5 | 2.5 | 2.4 | 2.6 | 2.8 | 2.8 | 0.5 |
| Nuclear | 1.8 | 1.8 | 2.5 | 2.9 | 2.6 | 2.5 | 2.4 | 1.0 |
| Renewables | 1.6 | 1.6 | 1.7 | 2.1 | 2.3 | 2.4 | 2.4 | 1.4 |
| Total | **11.9** | **12.6** | **13.1** | **13.9** | **14.1** | **14.4** | **14.2** | **0.4** |
| **Unspecified sector** | **-0.2** | **-0.5** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 6.9 | 7.0 | 7.7 | 8.1 | 8.0 | 8.0 | 7.7 | 0.3 |
| Natural gas | 15.7 | 16.1 | 15.7 | 16.2 | 16.6 | 16.9 | 16.4 | 0.1 |
| Coal | 4.7 | 5.4 | 5.3 | 5.3 | 5.5 | 5.7 | 5.5 | 0.1 |
| Nuclear | 1.8 | 1.8 | 2.5 | 2.9 | 2.6 | 2.5 | 2.4 | 1.0 |
| Renewables | 1.7 | 1.7 | 1.8 | 2.2 | 2.4 | 2.5 | 2.5 | 1.3 |
| Total | **30.9** | **32.1** | **33.2** | **34.7** | **35.1** | **35.5** | **34.5** | **0.3** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F12. Delivered energy consumption in Other Non-OECD Europe and Eurasia by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| Residential | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 |
| Natural gas | 1.8 | 1.8 | 2.3 | 2.5 | 2.7 | 2.9 | 3.0 | 1.8 |
| Coal | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.2 |
| Electricity | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 | 1.0 | 1.1 | 3.0 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| **Total** | **2.7** | **2.7** | **3.3** | **3.6** | **3.9** | **4.2** | **4.5** | **1.9** |
| Commercial | | | | | | | | |
| Liquids | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.9 |
| Natural gas | 0.6 | 0.6 | 0.8 | 0.9 | 1.0 | 1.1 | 1.1 | 1.9 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -0.3 |
| Electricity | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.6 | 0.7 | 2.9 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| **Total** | **1.1** | **1.0** | **1.3** | **1.5** | **1.6** | **1.7** | **1.8** | **2.1** |
| Industrial | | | | | | | | |
| Liquids | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 | 0.0 |
| Natural gas | 2.9 | 2.8 | 2.3 | 2.5 | 2.6 | 2.7 | 2.7 | -0.1 |
| Coal | 1.7 | 1.7 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | -0.8 |
| Electricity | 1.1 | 1.1 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | -0.2 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| **Total** | **7.2** | **6.9** | **5.7** | **6.0** | **6.3** | **6.5** | **6.5** | **-0.2** |
| Transportation | | | | | | | | |
| Liquids | 2.1 | 2.1 | 2.4 | 2.7 | 2.8 | 2.9 | 3.0 | 1.2 |
| Natural gas | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 2.5 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 |
| **Total** | **2.4** | **2.4** | **2.8** | **3.0** | **3.2** | **3.4** | **3.6** | **1.4** |
| All end-use sectors | | | | | | | | |
| Liquids | 3.7 | 3.6 | 3.8 | 4.1 | 4.3 | 4.4 | 4.5 | 0.8 |
| Natural gas | 5.6 | 5.5 | 5.7 | 6.3 | 6.8 | 7.1 | 7.3 | 1.0 |
| Coal | 2.0 | 1.9 | 1.4 | 1.5 | 1.5 | 1.5 | 1.5 | -0.7 |
| Electricity | 1.9 | 1.9 | 2.0 | 2.2 | 2.4 | 2.7 | 2.9 | 1.4 |
| Renewables | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| Delivered energy | **13.3** | **13.0** | **13.0** | **14.1** | **15.1** | **15.8** | **16.3** | **0.8** |
| Electricity-related losses | 5.7 | 5.6 | 5.7 | 5.9 | 6.2 | 6.5 | 6.8 | 0.7 |
| **Total** | **19.0** | **18.6** | **18.7** | **20.1** | **21.3** | **22.4** | **23.1** | **0.8** |
| Electric power[a] | | | | | | | | |
| Liquids | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -1.7 |
| Natural gas | 2.0 | 2.0 | 1.7 | 2.1 | 2.4 | 2.7 | 3.0 | 1.4 |
| Coal | 2.9 | 2.9 | 2.7 | 2.6 | 2.6 | 2.6 | 2.5 | -0.5 |
| Nuclear | 1.3 | 1.2 | 1.4 | 1.5 | 1.7 | 1.8 | 1.9 | 1.6 |
| Renewables | 1.2 | 1.2 | 1.5 | 1.5 | 1.5 | 1.7 | 1.8 | 1.6 |
| **Total** | **7.5** | **7.5** | **7.3** | **7.8** | **8.3** | **8.9** | **9.4** | **0.8** |
| Unspecified sector | **0.1** | **0.0** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **—** |
| Total energy consumption | | | | | | | | |
| Liquids | 3.9 | 3.8 | 4.3 | 4.6 | 4.7 | 4.8 | 4.9 | 1.0 |
| Natural gas | 7.6 | 7.5 | 7.4 | 8.3 | 9.1 | 9.8 | 10.3 | 1.1 |
| Coal | 5.0 | 4.8 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | -0.6 |
| Nuclear | 1.3 | 1.2 | 1.4 | 1.5 | 1.7 | 1.8 | 1.9 | 1.6 |
| Renewables | 1.3 | 1.3 | 1.6 | 1.6 | 1.6 | 1.8 | 1.9 | 1.5 |
| **Total** | **19.0** | **18.6** | **18.7** | **20.1** | **21.3** | **22.4** | **23.1** | **0.8** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F13. Delivered energy consumption in China by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 1.0 | 1.0 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 0.1 |
| Natural gas | 1.0 | 1.1 | 2.1 | 2.7 | 3.5 | 4.2 | 4.7 | 5.3 |
| Coal | 3.1 | 3.2 | 2.9 | 2.8 | 2.6 | 2.6 | 2.6 | -0.8 |
| Electricity | 2.0 | 2.2 | 3.4 | 4.3 | 5.0 | 5.8 | 6.8 | 4.1 |
| Renewables | 0.0 | 0.6 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 |
| Total | **7.1** | **8.2** | **10.2** | **11.6** | **13.0** | **14.4** | **15.9** | **2.4** |
| **Commercial** | | | | | | | | |
| Liquids | 0.5 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.4 |
| Natural gas | 0.3 | 0.3 | 0.5 | 0.6 | 0.7 | 0.8 | 0.8 | 3.2 |
| Coal | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | -0.6 |
| Electricity | 0.8 | 0.9 | 1.4 | 1.7 | 2.1 | 2.5 | 2.8 | 4.3 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **2.2** | **2.5** | **3.2** | **3.6** | **4.1** | **4.5** | **4.8** | **2.4** |
| **Industrial** | | | | | | | | |
| Liquids | 9.3 | 9.7 | 12.6 | 13.3 | 13.9 | 14.5 | 15.1 | 1.6 |
| Natural gas | 2.3 | 2.6 | 4.5 | 6.0 | 7.6 | 9.6 | 11.7 | 5.6 |
| Coal | 32.8 | 33.5 | 39.5 | 40.0 | 39.8 | 39.2 | 38.1 | 0.5 |
| Electricity | 11.6 | 12.0 | 16.2 | 17.5 | 18.3 | 19.1 | 19.7 | 1.8 |
| Renewables | 1.1 | 1.2 | 1.6 | 1.7 | 1.7 | 1.8 | 1.9 | 1.6 |
| Total | **56.9** | **59.0** | **74.5** | **78.5** | **81.4** | **84.2** | **86.4** | **1.4** |
| **Transportation** | | | | | | | | |
| Liquids | 11.4 | 12.6 | 17.1 | 19.0 | 20.6 | 22.0 | 22.9 | 2.2 |
| Natural gas | 0.1 | 0.1 | 0.4 | 0.8 | 1.6 | 2.5 | 3.3 | 13.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.1 | 0.2 | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 | 6.3 |
| Total | **11.6** | **12.8** | **17.9** | **20.3** | **22.8** | **25.1** | **27.1** | **2.7** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 22.1 | 24.0 | 31.7 | 34.2 | 36.4 | 38.3 | 39.8 | 1.8 |
| Natural gas | 3.6 | 4.1 | 7.5 | 10.3 | 13.5 | 17.0 | 20.5 | 5.9 |
| Coal | 36.4 | 37.4 | 43.0 | 43.3 | 43.0 | 42.3 | 41.2 | 0.3 |
| Electricity | 14.5 | 15.2 | 21.3 | 23.9 | 26.0 | 28.1 | 30.1 | 2.5 |
| Renewables | 1.1 | 1.8 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 1.3 |
| Delivered energy | **77.8** | **82.5** | **105.8** | **114.1** | **121.4** | **128.3** | **134.2** | **1.8** |
| Electricity-related losses | 31.7 | 32.5 | 41.5 | 45.3 | 49.0 | 52.4 | 55.9 | 2.0 |
| Total | **109.4** | **115.0** | **147.3** | **159.4** | **170.4** | **180.7** | **190.1** | **1.8** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.7 |
| Natural gas | 0.8 | 0.8 | 2.0 | 3.9 | 4.8 | 6.6 | 8.3 | 8.5 |
| Coal | 38.9 | 38.9 | 43.6 | 44.7 | 44.1 | 43.1 | 42.1 | 0.3 |
| Nuclear | 0.8 | 0.9 | 3.4 | 4.7 | 7.8 | 10.2 | 12.6 | 9.7 |
| Renewables | 7.8 | 9.5 | 18.8 | 21.2 | 23.7 | 26.2 | 28.7 | 4.0 |
| Total | **48.4** | **50.3** | **67.8** | **74.5** | **80.5** | **86.2** | **91.7** | **2.2** |
| **Unspecified sector** | **-2.1** | **-2.5** | **-5.0** | **-5.3** | **-5.5** | **-5.6** | **-5.7** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 19.5 | 20.9 | 26.7 | 29.0 | 31.0 | 32.7 | 34.1 | 1.8 |
| Natural gas | 4.9 | 5.3 | 9.5 | 14.1 | 18.3 | 23.7 | 28.8 | 6.2 |
| Coal | 75.4 | 76.5 | 86.6 | 88.0 | 87.0 | 85.4 | 83.3 | 0.3 |
| Nuclear | 0.8 | 0.9 | 3.4 | 4.7 | 7.8 | 10.2 | 12.6 | 9.7 |
| Renewables | 8.9 | 11.4 | 21.0 | 23.7 | 26.2 | 28.8 | 31.3 | 3.7 |
| Total | **109.4** | **115.0** | **147.3** | **159.4** | **170.4** | **180.7** | **190.1** | **1.8** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F14. Delivered energy consumption in India by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 1.0 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 0.2 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 2.8 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| Electricity | 0.7 | 0.8 | 1.4 | 1.8 | 2.3 | 2.9 | 3.5 | 5.5 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **2.0** | **2.1** | **2.8** | **3.3** | **3.8** | **4.3** | **5.0** | **3.2** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 3.4 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 2.8 |
| Coal | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 2.6 |
| Electricity | 0.3 | 0.3 | 0.5 | 0.6 | 0.7 | 0.8 | 1.0 | 4.2 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 |
| Total | **0.5** | **0.6** | **0.8** | **1.0** | **1.1** | **1.3** | **1.5** | **3.7** |
| **Industrial** | | | | | | | | |
| Liquids | 3.6 | 3.7 | 4.2 | 4.8 | 5.4 | 6.2 | 7.1 | 2.4 |
| Natural gas | 1.4 | 1.4 | 1.7 | 2.0 | 2.4 | 2.9 | 3.3 | 3.0 |
| Coal | 4.1 | 4.5 | 5.0 | 5.8 | 6.9 | 8.1 | 9.6 | 2.8 |
| Electricity | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 | 3.0 | 3.5 | 2.4 |
| Renewables | 1.7 | 1.7 | 1.8 | 2.0 | 2.3 | 2.8 | 3.2 | 2.2 |
| Total | **12.4** | **13.1** | **14.7** | **17.0** | **19.7** | **22.9** | **26.7** | **2.6** |
| **Transportation** | | | | | | | | |
| Liquids | 3.1 | 3.1 | 4.3 | 5.2 | 6.2 | 7.6 | 9.4 | 4.0 |
| Natural gas | 0.1 | 0.1 | 0.2 | 0.3 | 0.6 | 0.9 | 1.4 | 10.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 5.3 |
| Total | **3.2** | **3.3** | **4.6** | **5.6** | **6.9** | **8.7** | **10.9** | **4.4** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 7.7 | 8.0 | 9.8 | 11.3 | 12.9 | 15.1 | 17.8 | 2.9 |
| Natural gas | 1.6 | 1.6 | 2.0 | 2.5 | 3.2 | 4.0 | 4.9 | 4.1 |
| Coal | 4.4 | 4.7 | 5.3 | 6.1 | 7.2 | 8.5 | 10.0 | 2.7 |
| Electricity | 2.7 | 2.9 | 4.0 | 4.9 | 5.8 | 6.9 | 8.2 | 3.7 |
| Renewables | 1.7 | 1.8 | 1.8 | 2.0 | 2.4 | 2.8 | 3.3 | 2.2 |
| Delivered energy | **18.0** | **19.0** | **22.9** | **26.9** | **31.6** | **37.3** | **44.2** | **3.1** |
| Electricity-related losses | 6.9 | 7.2 | 9.9 | 11.6 | 13.3 | 15.5 | 18.2 | 3.4 |
| Total | **25.0** | **26.2** | **32.8** | **38.4** | **44.9** | **52.8** | **62.3** | **3.2** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| Natural gas | 0.8 | 0.6 | 0.4 | 0.5 | 0.8 | 1.2 | 1.4 | 3.3 |
| Coal | 7.5 | 8.2 | 10.0 | 10.5 | 11.0 | 12.6 | 14.7 | 2.1 |
| Nuclear | 0.4 | 0.4 | 0.8 | 1.3 | 2.2 | 2.4 | 2.6 | 7.3 |
| Renewables | 1.7 | 1.5 | 2.9 | 4.3 | 5.3 | 6.3 | 7.5 | 5.9 |
| Total | **10.4** | **10.8** | **14.1** | **16.7** | **19.4** | **22.6** | **26.4** | **3.2** |
| **Unspecified sector** | **-0.8** | **-0.7** | **-0.3** | **-0.3** | **-0.3** | **-0.2** | **-0.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 7.0 | 7.3 | 9.7 | 11.1 | 12.7 | 15.0 | 17.8 | 3.2 |
| Natural gas | 2.4 | 2.2 | 2.5 | 3.1 | 4.0 | 5.2 | 6.4 | 3.9 |
| Coal | 11.9 | 13.0 | 15.3 | 16.7 | 18.3 | 21.1 | 24.8 | 2.3 |
| Nuclear | 0.4 | 0.4 | 0.8 | 1.3 | 2.2 | 2.4 | 2.6 | 7.3 |
| Renewables | 3.3 | 3.3 | 4.7 | 6.4 | 7.7 | 9.1 | 10.8 | 4.3 |
| Total | **25.0** | **26.2** | **32.8** | **38.4** | **44.9** | **52.8** | **62.3** | **3.2** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F15. Delivered energy consumption in Other Non-OECD Asia by end-use sector and fuel, 2011–40
(quadrillion Btu)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Sector/fuel | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| **Residential** | | | | | | | | |
| Liquids | 0.6 | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.1 |
| Natural gas | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.6 | 0.7 | 1.7 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| Electricity | 1.1 | 1.2 | 1.6 | 1.9 | 2.2 | 2.5 | 2.9 | 3.2 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| Total | **2.2** | **2.3** | **2.8** | **3.2** | **3.5** | **3.9** | **4.3** | **2.3** |
| **Commercial** | | | | | | | | |
| Liquids | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 1.5 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 |
| Electricity | 0.9 | 1.0 | 1.4 | 1.7 | 2.0 | 2.4 | 2.7 | 3.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | **1.3** | **1.3** | **1.8** | **2.2** | **2.5** | **2.9** | **3.2** | **3.3** |
| **Industrial** | | | | | | | | |
| Liquids | 5.4 | 5.7 | 6.3 | 7.0 | 7.6 | 8.4 | 9.2 | 1.8 |
| Natural gas | 3.6 | 3.6 | 4.1 | 4.6 | 5.2 | 5.9 | 6.6 | 2.2 |
| Coal | 2.7 | 2.7 | 2.9 | 3.2 | 3.5 | 3.9 | 4.4 | 1.8 |
| Electricity | 1.5 | 1.6 | 1.8 | 2.0 | 2.2 | 2.5 | 2.8 | 2.0 |
| Renewables | 2.1 | 2.1 | 2.3 | 2.6 | 2.9 | 3.2 | 3.5 | 1.8 |
| Total | **15.2** | **15.7** | **17.4** | **19.4** | **21.5** | **23.9** | **26.6** | **1.9** |
| **Transportation** | | | | | | | | |
| Liquids | 7.1 | 7.3 | 8.4 | 9.6 | 10.9 | 12.6 | 14.6 | 2.5 |
| Natural gas | 0.3 | 0.3 | 0.7 | 1.0 | 1.3 | 1.7 | 2.4 | 7.6 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.3 |
| Total | **7.3** | **7.6** | **9.1** | **10.6** | **12.2** | **14.3** | **17.0** | **2.9** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 13.2 | 13.8 | 15.7 | 17.5 | 19.5 | 22.0 | 24.8 | 2.1 |
| Natural gas | 4.3 | 4.4 | 5.3 | 6.3 | 7.2 | 8.4 | 9.8 | 2.9 |
| Coal | 2.8 | 2.8 | 2.9 | 3.3 | 3.6 | 4.0 | 4.5 | 1.7 |
| Electricity | 3.6 | 3.8 | 4.8 | 5.6 | 6.5 | 7.5 | 8.5 | 2.9 |
| Renewables | 2.1 | 2.1 | 2.3 | 2.6 | 2.9 | 3.2 | 3.5 | 1.8 |
| Delivered energy | **26.0** | **26.9** | **31.2** | **35.3** | **39.8** | **45.0** | **51.1** | **2.3** |
| Electricity-related losses | 7.7 | 7.9 | 11.5 | 13.2 | 14.8 | 16.6 | 18.5 | 3.1 |
| Total | **33.7** | **34.7** | **42.7** | **48.6** | **54.6** | **61.6** | **69.6** | **2.5** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 1.3 | 1.2 | 1.1 | 1.1 | 1.0 | 1.0 | 0.9 | -0.7 |
| Natural gas | 3.5 | 3.6 | 4.1 | 4.6 | 5.6 | 6.7 | 7.6 | 2.6 |
| Coal | 3.1 | 3.3 | 4.4 | 5.0 | 5.4 | 6.1 | 7.0 | 2.7 |
| Nuclear | 0.4 | 0.4 | 0.6 | 0.9 | 0.9 | 0.9 | 1.0 | 2.9 |
| Renewables | 1.9 | 2.0 | 3.5 | 4.5 | 5.3 | 6.1 | 7.0 | 4.5 |
| Total | **10.2** | **10.6** | **13.8** | **16.1** | **18.4** | **20.8** | **23.4** | **2.9** |
| **Unspecified sector** | **1.1** | **1.1** | **2.5** | **2.7** | **3.0** | **3.2** | **3.5** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 15.6 | 16.0 | 19.4 | 21.3 | 23.5 | 26.2 | 29.3 | 2.2 |
| Natural gas | 7.8 | 8.0 | 9.5 | 10.9 | 12.9 | 15.1 | 17.4 | 2.8 |
| Coal | 5.9 | 6.1 | 7.4 | 8.3 | 9.1 | 10.1 | 11.5 | 2.3 |
| Nuclear | 0.4 | 0.4 | 0.6 | 0.9 | 0.9 | 0.9 | 1.0 | 2.9 |
| Renewables | 3.9 | 4.1 | 5.8 | 7.1 | 8.2 | 9.3 | 10.5 | 3.4 |
| Total | **33.7** | **34.7** | **42.7** | **48.6** | **54.6** | **61.6** | **69.6** | **2.5** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F16. Delivered energy consumption in the Middle East by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.1 |
| Natural gas | 1.7 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 1.0 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 1.2 | 1.3 | 1.7 | 2.0 | 2.3 | 2.7 | 3.1 | 3.3 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| **Total** | **3.5** | **3.5** | **4.1** | **4.5** | **4.9** | **5.4** | **5.9** | **1.9** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.0 |
| Natural gas | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.7 | 0.7 | 0.9 | 1.1 | 1.3 | 1.4 | 1.6 | 2.9 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| **Total** | **1.0** | **1.1** | **1.3** | **1.5** | **1.7** | **1.8** | **2.0** | **2.3** |
| **Industrial** | | | | | | | | |
| Liquids | 7.6 | 7.9 | 8.5 | 9.3 | 10.4 | 11.5 | 12.4 | 1.6 |
| Natural gas | 7.9 | 8.6 | 10.2 | 11.6 | 13.4 | 15.2 | 16.7 | 2.4 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 2.2 |
| Electricity | 0.6 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 | 2.1 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 |
| **Total** | **16.1** | **17.1** | **19.4** | **21.7** | **24.7** | **27.7** | **30.3** | **2.1** |
| **Transportation** | | | | | | | | |
| Liquids | 5.0 | 5.2 | 5.7 | 6.4 | 7.0 | 7.7 | 8.3 | 1.7 |
| Natural gas | 0.2 | 0.3 | 0.6 | 0.7 | 0.8 | 0.9 | 1.1 | 5.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.2 |
| **Total** | **5.2** | **5.5** | **6.3** | **7.1** | **7.9** | **8.6** | **9.4** | **1.9** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 13.4 | 13.9 | 15.1 | 16.5 | 18.3 | 20.0 | 21.6 | 1.6 |
| Natural gas | 10.0 | 10.6 | 12.6 | 14.3 | 16.3 | 18.3 | 20.1 | 2.3 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 2.2 |
| Electricity | 2.4 | 2.5 | 3.2 | 3.8 | 4.4 | 5.0 | 5.7 | 3.0 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 |
| Delivered energy | **25.9** | **27.1** | **31.0** | **34.8** | **39.2** | **43.6** | **47.5** | **2.0** |
| Electricity-related losses | 4.0 | 4.6 | 9.8 | 10.6 | 11.6 | 13.0 | 14.3 | 4.2 |
| **Total** | **29.9** | **31.7** | **40.8** | **45.4** | **50.7** | **56.6** | **61.8** | **2.4** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 2.6 | 2.8 | 2.5 | 1.7 | 1.3 | 1.2 | 1.2 | -3.2 |
| Natural gas | 4.5 | 4.8 | 6.0 | 7.2 | 8.4 | 9.1 | 10.3 | 2.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | — |
| Nuclear | 0.0 | 0.0 | 0.4 | 0.6 | 1.0 | 1.3 | 1.6 | 18.5 |
| Renewables | 0.2 | 0.2 | 0.7 | 1.4 | 1.5 | 2.3 | 2.6 | 9.3 |
| **Total** | **7.3** | **7.8** | **9.7** | **11.0** | **12.2** | **14.0** | **15.6** | **2.5** |
| **Unspecified sector** | **-0.9** | **-0.7** | **3.3** | **3.5** | **3.7** | **4.1** | **4.4** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 15.1 | 16.0 | 20.9 | 21.7 | 23.3 | 25.3 | 27.1 | 1.9 |
| Natural gas | 14.5 | 15.4 | 18.6 | 21.5 | 24.7 | 27.4 | 30.3 | 2.5 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 3.2 |
| Nuclear | 0.0 | 0.0 | 0.4 | 0.6 | 1.0 | 1.3 | 1.6 | 18.5 |
| Renewables | 0.2 | 0.2 | 0.8 | 1.4 | 1.6 | 2.3 | 2.6 | 9.0 |
| **Total** | **29.9** | **31.7** | **40.8** | **45.4** | **50.7** | **56.6** | **61.8** | **2.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F17. Delivered energy consumption in Africa by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.3 |
| Natural gas | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 1.9 |
| Coal | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 |
| Electricity | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | 1.6 | 1.9 | 3.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 |
| Total | **1.6** | **1.8** | **2.2** | **2.4** | **2.7** | **3.0** | **3.4** | **2.2** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.5 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 2.3 |
| Electricity | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 1.0 | 3.7 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 |
| Total | **0.5** | **0.5** | **0.7** | **0.8** | **0.9** | **1.1** | **1.3** | **3.2** |
| **Industrial** | | | | | | | | |
| Liquids | 1.9 | 1.9 | 2.1 | 2.4 | 2.6 | 2.9 | 3.3 | 2.0 |
| Natural gas | 1.8 | 2.0 | 2.5 | 2.9 | 3.3 | 3.7 | 4.1 | 2.6 |
| Coal | 1.7 | 1.7 | 1.9 | 2.2 | 2.4 | 2.7 | 3.0 | 2.0 |
| Electricity | 1.0 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 2.1 |
| Renewables | 3.2 | 3.4 | 3.9 | 4.4 | 5.1 | 5.8 | 6.6 | 2.4 |
| Total | **9.5** | **10.0** | **11.4** | **13.1** | **14.8** | **16.7** | **18.8** | **2.3** |
| **Transportation** | | | | | | | | |
| Liquids | 4.1 | 4.2 | 5.2 | 6.0 | 6.6 | 7.5 | 8.7 | 2.6 |
| Natural gas | 0.0 | 0.0 | 0.1 | 0.2 | 0.6 | 0.9 | 1.3 | 13.5 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 3.4 |
| Total | **4.1** | **4.3** | **5.3** | **6.2** | **7.2** | **8.4** | **10.1** | **3.1** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 6.7 | 6.9 | 8.2 | 9.2 | 10.1 | 11.3 | 12.9 | 2.3 |
| Natural gas | 2.1 | 2.4 | 3.0 | 3.5 | 4.3 | 5.1 | 6.0 | 3.3 |
| Coal | 1.9 | 2.0 | 2.2 | 2.5 | 2.7 | 3.0 | 3.3 | 1.9 |
| Electricity | 2.0 | 2.0 | 2.5 | 2.9 | 3.4 | 4.1 | 4.7 | 3.0 |
| Renewables | 3.2 | 3.4 | 3.9 | 4.5 | 5.1 | 5.8 | 6.6 | 2.4 |
| Delivered energy | **15.8** | **16.7** | **19.7** | **22.6** | **25.6** | **29.2** | **33.5** | **2.5** |
| Electricity-related losses | 4.3 | 4.8 | 6.5 | 7.4 | 8.1 | 9.2 | 10.4 | 2.8 |
| Total | **20.1** | **21.5** | **26.1** | **30.0** | **33.8** | **38.4** | **44.0** | **2.6** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.5 | 0.6 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | -0.4 |
| Natural gas | 2.0 | 2.3 | 2.8 | 3.0 | 3.8 | 4.8 | 5.7 | 3.3 |
| Coal | 2.7 | 2.8 | 3.2 | 3.3 | 3.3 | 3.4 | 3.6 | 0.9 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 4.4 |
| Renewables | 1.1 | 1.1 | 1.5 | 2.3 | 2.7 | 3.2 | 3.7 | 4.3 |
| Total | **6.5** | **7.0** | **8.3** | **9.5** | **10.7** | **12.3** | **14.0** | **2.5** |
| **Unspecified sector** | **-0.2** | **-0.1** | **0.7** | **0.8** | **0.8** | **1.0** | **1.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 7.0 | 7.4 | 9.5 | 10.6 | 11.6 | 12.8 | 14.6 | 2.5 |
| Natural gas | 4.1 | 4.7 | 5.8 | 6.6 | 8.1 | 9.9 | 11.7 | 3.3 |
| Coal | 4.6 | 4.8 | 5.4 | 5.8 | 6.0 | 6.4 | 7.0 | 1.4 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 4.4 |
| Renewables | 4.3 | 4.5 | 5.4 | 6.8 | 7.8 | 9.0 | 10.3 | 3.0 |
| Total | **20.1** | **21.5** | **26.1** | **30.0** | **33.8** | **38.4** | **44.0** | **2.6** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F18. Delivered energy consumption in Brazil by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.0 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.5 | 0.5 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 2.4 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **0.7** | **0.8** | **0.9** | **0.9** | **1.0** | **1.1** | **1.2** | **1.6** |
| **Commercial** | | | | | | | | |
| Liquids | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 |
| Natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 1.8 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total | **0.5** | **0.5** | **0.6** | **0.6** | **0.7** | **0.8** | **0.8** | **1.8** |
| **Industrial** | | | | | | | | |
| Liquids | 2.9 | 3.0 | 2.8 | 3.0 | 3.2 | 3.5 | 3.7 | 0.8 |
| Natural gas | 0.7 | 0.8 | 0.8 | 1.0 | 1.1 | 1.3 | 1.5 | 2.4 |
| Coal | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 |
| Electricity | 0.7 | 0.7 | 0.7 | 0.8 | 0.9 | 1.1 | 1.2 | 1.9 |
| Renewables | 2.5 | 2.5 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 0.6 |
| Total | **7.3** | **7.5** | **6.9** | **7.7** | **8.4** | **9.2** | **10.0** | **1.0** |
| **Transportation** | | | | | | | | |
| Liquids | 2.8 | 2.8 | 3.0 | 3.3 | 3.7 | 4.0 | 4.4 | 1.6 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 3.7 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 |
| Total | **2.9** | **2.9** | **3.1** | **3.4** | **3.8** | **4.2** | **4.7** | **1.7** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 5.9 | 6.1 | 6.1 | 6.7 | 7.3 | 7.8 | 8.5 | 1.2 |
| Natural gas | 0.8 | 0.9 | 0.9 | 1.1 | 1.3 | 1.5 | 1.8 | 2.5 |
| Coal | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 |
| Electricity | 1.6 | 1.6 | 1.8 | 2.0 | 2.3 | 2.6 | 2.9 | 2.0 |
| Renewables | 2.5 | 2.5 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 0.6 |
| Delivered energy | **11.4** | **11.6** | **11.4** | **12.7** | **13.9** | **15.2** | **16.7** | **1.3** |
| Electricity-related losses | 3.4 | 3.6 | 4.9 | 5.5 | 6.1 | 6.8 | 7.6 | 2.7 |
| Total | **14.8** | **15.2** | **16.3** | **18.1** | **20.0** | **22.0** | **24.3** | **1.7** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | -0.6 |
| Natural gas | 0.1 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 2.3 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.4 |
| Nuclear | 0.2 | 0.2 | 0.3 | 0.3 | 0.6 | 0.6 | 0.6 | 4.8 |
| Renewables | 4.5 | 4.3 | 4.7 | 5.5 | 6.0 | 7.0 | 8.1 | 2.3 |
| Total | **4.9** | **5.0** | **5.8** | **6.6** | **7.4** | **8.3** | **9.4** | **2.3** |
| **Unspecified sector** | **0.2** | **0.3** | **0.9** | **0.9** | **1.0** | **1.1** | **1.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 6.2 | 6.6 | 7.1 | 7.8 | 8.4 | 9.0 | 9.7 | 1.4 |
| Natural gas | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.0 | 2.3 | 2.6 |
| Coal | 0.5 | 0.6 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 |
| Nuclear | 0.2 | 0.2 | 0.3 | 0.3 | 0.6 | 0.6 | 0.6 | 4.8 |
| Renewables | 7.0 | 6.8 | 7.0 | 8.0 | 8.6 | 9.8 | 11.1 | 1.7 |
| Total | **14.8** | **15.2** | **16.3** | **18.1** | **20.0** | **22.0** | **24.3** | **1.7** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table F19. Delivered energy consumption in Other Non-OECD Americas by end-use sector and fuel, 2011–40
(quadrillion Btu)

| Sector/fuel | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **Residential** | | | | | | | | |
| Liquids | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.0 |
| Natural gas | 0.4 | 0.4 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | 2.1 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| Electricity | 0.5 | 0.5 | 0.7 | 0.7 | 0.8 | 0.9 | 1.0 | 2.3 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | **1.3** | **1.3** | **1.6** | **1.7** | **1.8** | **2.0** | **2.1** | **1.8** |
| **Commercial** | | | | | | | | |
| Liquids | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.1 |
| Natural gas | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.4 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 2.2 |
| Renewables | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | **0.5** | **0.5** | **0.6** | **0.7** | **0.8** | **0.8** | **0.9** | **2.0** |
| **Industrial** | | | | | | | | |
| Liquids | 2.5 | 2.5 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 0.2 |
| Natural gas | 2.6 | 2.4 | 2.4 | 2.6 | 2.7 | 3.0 | 3.2 | 1.0 |
| Coal | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 1.3 |
| Electricity | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.5 |
| Renewables | 0.6 | 0.6 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.0 |
| Total | **6.4** | **6.3** | **5.9** | **6.3** | **6.6** | **7.0** | **7.5** | **0.6** |
| **Transportation** | | | | | | | | |
| Liquids | 3.3 | 3.3 | 3.7 | 4.0 | 4.2 | 4.5 | 5.0 | 1.4 |
| Natural gas | 0.2 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 5.8 |
| Coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Electricity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 |
| Total | **3.5** | **3.6** | **4.1** | **4.5** | **5.0** | **5.5** | **6.2** | **2.0** |
| **All end-use sectors** | | | | | | | | |
| Liquids | 6.1 | 6.2 | 6.4 | 6.8 | 7.1 | 7.5 | 8.1 | 0.9 |
| Natural gas | 3.3 | 3.2 | 3.4 | 3.9 | 4.3 | 4.8 | 5.2 | 1.8 |
| Coal | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 1.3 |
| Electricity | 1.5 | 1.5 | 1.7 | 1.9 | 2.0 | 2.2 | 2.4 | 1.6 |
| Renewables | 0.6 | 0.6 | 0.5 | 0.5 | 0.6 | 0.6 | 0.6 | 0.0 |
| Delivered energy | **11.7** | **11.7** | **12.2** | **13.3** | **14.2** | **15.3** | **16.6** | **1.3** |
| Electricity-related losses | 4.0 | 4.1 | 5.0 | 5.3 | 5.6 | 6.0 | 6.4 | 1.6 |
| Total | **15.7** | **15.8** | **17.2** | **18.6** | **19.8** | **21.2** | **23.0** | **1.4** |
| **Electric power**[a] | | | | | | | | |
| Liquids | 1.0 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 0.9 | -0.6 |
| Natural gas | 1.1 | 1.2 | 1.4 | 1.5 | 1.7 | 1.9 | 2.1 | 2.0 |
| Coal | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 1.2 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 5.8 |
| Renewables | 2.9 | 2.8 | 3.0 | 3.4 | 3.6 | 3.9 | 4.3 | 1.4 |
| Total | **5.3** | **5.3** | **5.7** | **6.2** | **6.6** | **7.2** | **7.7** | **1.4** |
| **Unspecified sector** | **0.3** | **0.3** | **1.0** | **1.0** | **1.0** | **1.0** | **1.1** | **—** |
| **Total energy consumption** | | | | | | | | |
| Liquids | 7.4 | 7.7 | 8.5 | 8.8 | 9.1 | 9.5 | 10.1 | 1.0 |
| Natural gas | 4.4 | 4.3 | 4.8 | 5.4 | 6.0 | 6.6 | 7.3 | 1.9 |
| Coal | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 1.3 |
| Nuclear | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 5.8 |
| Renewables | 3.5 | 3.4 | 3.5 | 3.9 | 4.2 | 4.5 | 4.9 | 1.2 |
| Total | **15.7** | **15.8** | **17.2** | **18.6** | **19.8** | **21.2** | **23.0** | **1.4** |

[a]Fuel inputs used in the production of electricity and heat, excluding captive generators.

Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies; and International Energy Agency, "Balances of OECD and Non-OECD Statistics" (2014), www.iea.org (subscription site). **Projections:** EIA, World Energy Projection System Plus (2015), run reference_final_2016.02.19_115008.

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## Appendix G

# Projections of petroleum and other liquids production in three cases

- *Reference*
- *High Oil Price*
- *Low Oil Price*

## Table G1. World petroleum and other liquids production by region and country, Reference case, 2011–40
(million barrels per day, unless otherwise noted)

| | History (estimates) | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region/country | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| **OPEC[a]** | **36.0** | **37.4** | **39.2** | **41.4** | **44.6** | **48.7** | **52.2** | **1.2** |
| Middle East | 26.2 | 26.6 | 29.8 | 31.7 | 34.3 | 37.7 | 40.1 | 1.5 |
| North Africa | 2.4 | 3.3 | 2.0 | 2.1 | 2.3 | 2.6 | 3.0 | -0.4 |
| West Africa | 4.3 | 4.3 | 4.3 | 4.4 | 4.6 | 4.8 | 5.2 | 0.7 |
| South America | 3.2 | 3.2 | 3.0 | 3.1 | 3.4 | 3.6 | 3.9 | 0.7 |
| Non-OPEC | **52.4** | **53.0** | **61.1** | **63.1** | **64.4** | **65.9** | **68.7** | **0.9** |
| OECD | **21.6** | **22.5** | **29.2** | **28.8** | **28.6** | **28.2** | **28.9** | **0.9** |
| OECD Americas | **16.7** | **17.9** | **24.9** | **24.7** | **24.7** | **24.5** | **25.2** | **1.2** |
| United States | 10.1 | 11.1 | 17.0 | 16.7 | 16.5 | 15.8 | 15.9 | 1.3 |
| Canada | 3.6 | 3.9 | 5.4 | 5.4 | 5.5 | 5.7 | 6.0 | 1.6 |
| Mexico and Chile | 3.0 | 3.0 | 2.5 | 2.6 | 2.6 | 2.9 | 3.3 | 0.4 |
| OECD Europe | **4.1** | **3.8** | **3.5** | **3.3** | **3.1** | **2.9** | **2.8** | **-1.1** |
| North Sea | 3.3 | 3.0 | 2.5 | 2.3 | 2.1 | 1.9 | 1.7 | -2.0 |
| Other | 0.8 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 |
| OECD Asia | **0.8** | **0.8** | **0.8** | **0.8** | **0.8** | **0.9** | **1.0** | **0.8** |
| Australia and New Zealand | 0.6 | 0.6 | 0.7 | 0.6 | 0.6 | 0.7 | 0.8 | 1.0 |
| Other | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.2 |
| Non-OECD | **30.9** | **30.5** | **31.9** | **34.3** | **35.9** | **37.7** | **39.8** | **1.0** |
| Non-OECD Europe and Eurasia | **13.7** | **13.8** | **13.8** | **15.2** | **15.9** | **16.4** | **17.1** | **0.8** |
| Russia | **10.4** | **10.6** | **10.1** | **10.9** | **11.3** | **11.8** | **12.5** | **0.6** |
| Caspian Area | **3.0** | **2.9** | **3.4** | **4.1** | **4.4** | **4.4** | **4.4** | **1.5** |
| Kazakhstan | 1.6 | 1.6 | 2.3 | 2.9 | 3.2 | 3.3 | 3.2 | 2.5 |
| Other | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | -0.3 |
| Other | **0.3** | **0.3** | **0.3** | **0.3** | **0.2** | **0.2** | **0.2** | **-1.0** |
| Non-OECD Asia | **8.2** | **8.3** | **8.9** | **9.1** | **9.2** | **9.6** | **9.9** | **0.6** |
| China | 4.4 | 4.4 | 4.9 | 5.2 | 5.5 | 6.0 | 6.3 | 1.2 |
| India | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 0.5 |
| Other | 2.8 | 2.9 | 2.9 | 2.7 | 2.6 | 2.5 | 2.5 | -0.5 |
| Middle East (Non-OPEC) | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.8** | **0.7** | **-2.3** |
| Oman | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | -2.1 |
| Other | 0.6 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -2.7 |
| Africa | **2.6** | **2.3** | **2.4** | **2.5** | **2.6** | **2.7** | **2.8** | **0.7** |
| Ghana | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 2.9 |
| Other | 2.5 | 2.2 | 2.2 | 2.3 | 2.5 | 2.5 | 2.6 | 0.6 |
| Non-OECD Americas | **4.8** | **4.8** | **5.7** | **6.6** | **7.3** | **8.2** | **9.3** | **2.4** |
| Brazil | 2.7 | 2.7 | 3.6 | 4.5 | 5.1 | 5.6 | 6.3 | 3.1 |
| Other | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.6 | 3.0 | 1.2 |
| Total World | **88.5** | **90.4** | **100.3** | **104.5** | **109.1** | **114.6** | **120.9** | **1.0** |
| OPEC share of world production | 41% | 41% | 39% | 40% | 41% | 42% | 43% | |
| Persian Gulf share of world production | 30% | 29% | 30% | 30% | 31% | 33% | 33% | |

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_BaseCase-IEO.xlsm]A4. Petroleum & Other Liquids.

## Table G2. World crude oil[a] production by region and country, Reference case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **32.2** | **33.4** | **34.9** | **36.8** | **39.7** | **43.4** | **46.6** | **1.2** |
| Middle East | 22.9 | 23.2 | 26.2 | 27.9 | 30.3 | 33.4 | 35.6 | 1.5 |
| North Africa | 2.0 | 2.9 | 1.6 | 1.7 | 1.8 | 2.0 | 2.2 | -1.0 |
| West Africa | 4.3 | 4.3 | 4.3 | 4.3 | 4.5 | 4.7 | 5.1 | 0.6 |
| South America | 3.0 | 3.0 | 2.8 | 2.9 | 3.1 | 3.4 | 3.6 | 0.7 |
| **Non-OPEC** | **42.5** | **42.8** | **47.9** | **49.1** | **49.7** | **50.7** | **52.9** | **0.8** |
| **OECD** | **14.9** | **15.7** | **20.3** | **19.6** | **19.2** | **18.9** | **19.5** | **0.8** |
| **OECD Americas** | **11.2** | **12.2** | **17.4** | **16.9** | **16.9** | **16.7** | **17.4** | **1.3** |
| United States | 5.7 | 6.5 | 10.6 | 10.3 | 10.0 | 9.4 | 9.4 | 1.3 |
| Canada | 2.9 | 3.1 | 4.6 | 4.4 | 4.5 | 4.7 | 5.0 | 1.6 |
| Mexico and Chile | 2.6 | 2.6 | 2.2 | 2.2 | 2.3 | 2.6 | 3.0 | 0.5 |
| **OECD Europe** | **3.3** | **3.0** | **2.4** | **2.1** | **1.9** | **1.6** | **1.5** | **-2.5** |
| North Sea | 2.8 | 2.5 | 2.0 | 1.8 | 1.6 | 1.4 | 1.3 | -2.4 |
| Other | 0.5 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | -3.0 |
| **OECD Asia** | **0.5** | **0.5** | **0.5** | **0.5** | **0.5** | **0.6** | **0.6** | **1.2** |
| Australia and New Zealand | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 1.2 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.2 |
| **Non-OECD** | **27.6** | **27.1** | **27.6** | **29.5** | **30.5** | **31.8** | **33.4** | **0.8** |
| **Non-OECD Europe and Eurasia** | **12.8** | **12.9** | **12.8** | **14.2** | **14.9** | **15.5** | **16.2** | **0.8** |
| **Russia** | **9.8** | **9.9** | **9.3** | **10.1** | **10.6** | **11.0** | **11.8** | **0.6** |
| **Caspian Area** | **2.8** | **2.7** | **3.2** | **3.9** | **4.2** | **4.3** | **4.2** | **1.6** |
| Kazakhstan | 1.6 | 1.5 | 2.2 | 2.8 | 3.1 | 3.2 | 3.1 | 2.6 |
| Other | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | -0.3 |
| **Other** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **-1.3** |
| **Non-OECD Asia** | **7.2** | **7.2** | **7.4** | **7.2** | **7.0** | **7.1** | **6.9** | **-0.2** |
| China | 4.1 | 4.1 | 4.3 | 4.5 | 4.4 | 4.7 | 4.7 | 0.5 |
| India | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | -0.4 |
| Other | 2.4 | 2.4 | 2.3 | 2.0 | 1.9 | 1.7 | 1.6 | -1.4 |
| **Middle East (Non-OPEC)** | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.7** | **0.7** | **-2.3** |
| **Africa** | **2.2** | **1.9** | **1.9** | **2.0** | **2.2** | **2.2** | **2.3** | **0.7** |
| **Non-OECD Americas** | **3.9** | **3.8** | **4.5** | **5.2** | **5.6** | **6.3** | **7.3** | **2.3** |
| Brazil | 2.1 | 2.1 | 2.8 | 3.5 | 3.9 | 4.2 | 4.8 | 3.1 |
| Other | 1.8 | 1.8 | 1.7 | 1.6 | 1.7 | 2.1 | 2.5 | 1.3 |
| **Total World** | **74.7** | **76.2** | **82.7** | **85.8** | **89.5** | **94.1** | **99.5** | **1.0** |
| OPEC share of world production | 43% | 44% | 42% | 43% | 44% | 46% | 47% | |
| Persian Gulf share of world production | 31% | 30% | 32% | 32% | 34% | 35% | 36% | |

[a]Crude oil production also includes tight oil, shale oil, extra-heavy oil, field condensate, and bitumen.
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_BaseCase-IEO.xlsm]A5. Crude & LC Production.

## Table G3. International other liquid fuels[a] production by region and country, Reference case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **3.7** | **3.8** | **4.3** | **4.6** | **4.8** | **5.2** | **5.6** | **1.3** |
| Natural gas plant liquids | 3.6 | 3.7 | 4.0 | 4.3 | 4.5 | 4.8 | 5.1 | 1.2 |
| Liquids from renewable sources[c] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from natural gas | 0.1 | 0.1 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 5.5 |
| Refinery gain | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| **Non-OPEC** | **9.9** | **10.2** | **13.2** | **14.0** | **14.7** | **15.2** | **15.8** | **1.6** |
| **OECD** | **6.6** | **6.8** | **8.9** | **9.2** | **9.3** | **9.4** | **9.4** | **1.2** |
| Natural gas plant liquids | 3.6 | 3.8 | 5.5 | 5.7 | 5.8 | 5.7 | 5.6 | 1.4 |
| Liquids from renewable sources[c] | 1.3 | 1.3 | 1.5 | 1.5 | 1.6 | 1.6 | 1.8 | 1.2 |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Liquids from natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from kerogen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| Refinery processing gain | 1.7 | 1.7 | 1.9 | 2.0 | 2.0 | 2.0 | 2.1 | 0.6 |
| **Non-OECD** | **3.3** | **3.4** | **4.3** | **4.8** | **5.4** | **5.9** | **6.4** | **2.3** |
| Natural gas plant liquids | 1.8 | 1.8 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 0.5 |
| Liquids from renewable sources[c] | 0.6 | 0.7 | 1.0 | 1.3 | 1.7 | 2.1 | 2.4 | 4.7 |
| Liquids from coal | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.4 | 0.5 | 3.5 |
| Liquids from natural gas | 0.1 | 0.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 6.2 |
| Refinery gain | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.1 | 2.0 |
| **Total World** | **13.7** | **14.0** | **17.5** | **18.6** | **19.6** | **20.5** | **21.4** | **1.5** |
| **Natural gas plant liquids** | **9.0** | **9.4** | **11.7** | **12.2** | **12.4** | **12.6** | **12.9** | **1.1** |
| United States | 2.2 | 2.4 | 4.0 | 4.2 | 4.2 | 4.1 | 4.1 | 1.9 |
| Russia | 0.6 | 0.6 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.1 |
| **Liquids from renewable sources[c]** | **1.9** | **1.9** | **2.5** | **2.9** | **3.3** | **3.7** | **4.1** | **2.8** |
| Brazil | 0.4 | 0.4 | 0.6 | 0.8 | 1.0 | 1.1 | 1.2 | 3.9 |
| China | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 9.9 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 5.8 |
| United States | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.7 |
| **Liquids from coal** | **0.2** | **0.2** | **0.3** | **0.2** | **0.3** | **0.4** | **0.5** | **3.4** |
| Australia and New Zealand | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| China | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 10.2 |
| Germany | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| South Africa | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| United States | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| **Liquids from natural gas** | **0.1** | **0.1** | **0.3** | **0.5** | **0.6** | **0.6** | **0.7** | **5.7** |
| Qatar | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 5.0 |
| South Africa | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 0.2 | 7.4 |
| **Refinery processing gain** | **2.4** | **2.4** | **2.7** | **2.9** | **3.0** | **3.1** | **3.2** | **1.1** |
| United States | 1.1 | 1.1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 0.7 |
| China | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 2.3 |

[a]Other liquid fuels include natural gas plant liquids, liquids from renewable sources (biofuels, including ethanol, biodiesel, and biomass-to-liquids [BTL]), liquids from natural gas (gas-to-liquids [GTL]), liquids from coal (coal-to-liquids [CTL]), and liquids from kerogen (oil shale).
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
[c]Liquids from renewable sources (biofuels) include ethanol, biodiesel, and biomass-to-liquids (BTL). All values, including ethanol, are reported on a volume basis.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_BaseCase-IEO.xlsm]A6. Other Liquids.

## Table G4. World petroleum and other liquids production by region and country, High Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[a]** | **36.0** | **37.4** | **35.3** | **35.8** | **37.7** | **39.3** | **40.4** | **0.3** |
| Middle East | 26.2 | 26.6 | 26.5 | 27.0 | 28.6 | 29.8 | 30.6 | 0.5 |
| North Africa | 2.4 | 3.3 | 2.1 | 1.9 | 2.1 | 2.2 | 2.3 | -1.4 |
| West Africa | 4.3 | 4.3 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | -0.2 |
| South America | 3.2 | 3.2 | 2.8 | 2.9 | 3.0 | 3.2 | 3.5 | 0.3 |
| Non-OPEC | **52.4** | **53.0** | **61.5** | **65.4** | **68.1** | **72.6** | **78.1** | **1.4** |
| OECD | **21.6** | **22.5** | **31.7** | **33.6** | **34.2** | **35.3** | **36.9** | **1.8** |
| OECD Americas | **16.7** | **17.9** | **27.4** | **29.3** | **29.9** | **31.0** | **32.4** | **2.1** |
| United States | 10.1 | 11.1 | 19.0 | 20.0 | 19.8 | 19.2 | 18.2 | 1.8 |
| Canada | 3.6 | 3.9 | 5.5 | 6.0 | 6.5 | 7.6 | 8.8 | 3.0 |
| Mexico and Chile | 3.0 | 3.0 | 2.9 | 3.3 | 3.6 | 4.2 | 5.4 | 2.2 |
| OECD Europe | **4.1** | **3.8** | **3.4** | **3.2** | **3.0** | **2.8** | **2.8** | **-1.1** |
| North Sea | 3.3 | 3.0 | 2.4 | 2.2 | 2.0 | 1.8 | 1.7 | -2.0 |
| Other | 0.8 | 0.8 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.0 |
| OECD Asia | **0.8** | **0.8** | **0.9** | **1.1** | **1.2** | **1.5** | **1.7** | **2.9** |
| Australia and New Zealand | 0.6 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | 1.5 | 3.6 |
| Other | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.4 |
| Non-OECD | **30.9** | **30.5** | **29.9** | **31.8** | **33.9** | **37.2** | **41.2** | **1.1** |
| Non-OECD Europe and Eurasia | **13.7** | **13.8** | **12.4** | **12.8** | **13.4** | **15.1** | **16.9** | **0.7** |
| **Russia** | **10.4** | **10.6** | **9.2** | **9.4** | **9.3** | **10.3** | **11.1** | **0.2** |
| **Caspian Area** | **3.0** | **2.9** | **2.9** | **3.1** | **3.8** | **4.5** | **5.5** | **2.3** |
| Kazakhstan | 1.6 | 1.6 | 1.7 | 2.0 | 2.6 | 3.4 | 4.3 | 3.6 |
| Other | 1.3 | 1.3 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | -0.3 |
| **Other** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.2** | **0.2** | **-0.9** |
| Non-OECD Asia | **8.2** | **8.3** | **8.7** | **9.0** | **9.3** | **9.9** | **10.4** | **0.8** |
| China | 4.4 | 4.4 | 4.8 | 5.2 | 5.6 | 6.2 | 6.7 | 1.5 |
| India | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.2 | 0.6 |
| Other | 2.8 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 | 2.6 | -0.4 |
| Middle East (Non-OPEC) | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.8** | **0.7** | **-2.3** |
| Oman | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | -2.1 |
| Other | 0.6 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -2.6 |
| Africa | **2.6** | **2.3** | **2.4** | **2.5** | **2.7** | **2.8** | **3.0** | **1.0** |
| Ghana | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 3.3 |
| Other | 2.5 | 2.2 | 2.2 | 2.3 | 2.5 | 2.6 | 2.8 | 0.9 |
| Non-OECD Americas | **4.8** | **4.8** | **5.5** | **6.6** | **7.7** | **8.7** | **10.2** | **2.7** |
| Brazil | 2.7 | 2.7 | 3.2 | 4.1 | 4.7 | 5.1 | 5.9 | 2.9 |
| Other | 2.1 | 2.1 | 2.2 | 2.5 | 3.0 | 3.5 | 4.3 | 2.5 |
| Total World | **88.5** | **90.4** | **96.9** | **101.2** | **105.8** | **111.8** | **118.5** | **1.0** |
| OPEC share of world production | 41% | 41% | 36% | 35% | 36% | 35% | 34% | |
| Persian Gulf share of world production | 30% | 29% | 27% | 27% | 27% | 27% | 26% | |

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_HighPriceCase-IEO.xlsm]A4. Petroleum & Other Liquids

## Table G5. World crude oil[a] production by region and country, High Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **32.2** | **33.4** | **30.7** | **30.9** | **32.4** | **33.4** | **34.4** | **0.1** |
| Middle East | 22.9 | 23.2 | 22.7 | 23.0 | 24.4 | 25.2 | 25.9 | 0.4 |
| North Africa | 2.0 | 2.9 | 1.6 | 1.4 | 1.4 | 1.4 | 1.4 | -2.5 |
| West Africa | 4.3 | 4.3 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | -0.4 |
| South America | 3.0 | 3.0 | 2.5 | 2.6 | 2.7 | 2.9 | 3.2 | 0.2 |
| Non-OPEC | **42.5** | **42.8** | **47.8** | **50.3** | **51.5** | **54.2** | **57.8** | **1.1** |
| OECD | **14.9** | **15.7** | **22.5** | **24.0** | **24.2** | **24.7** | **25.8** | **1.8** |
| OECD Americas | **11.2** | **12.2** | **19.6** | **21.2** | **21.5** | **22.0** | **23.0** | **2.3** |
| United States | 5.7 | 6.5 | 12.3 | 13.0 | 12.5 | 11.4 | 9.9 | 1.5 |
| Canada | 2.9 | 3.1 | 4.6 | 5.2 | 5.7 | 6.8 | 8.0 | 3.4 |
| Mexico and Chile | 2.6 | 2.6 | 2.6 | 3.0 | 3.3 | 3.8 | 5.1 | 2.4 |
| OECD Europe | **3.3** | **3.0** | **2.3** | **2.1** | **1.8** | **1.6** | **1.4** | **-2.6** |
| North Sea | 2.8 | 2.5 | 1.9 | 1.8 | 1.5 | 1.4 | 1.2 | -2.5 |
| Other | 0.5 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | -3.0 |
| OECD Asia | **0.5** | **0.5** | **0.6** | **0.8** | **1.0** | **1.2** | **1.4** | **4.1** |
| Australia and New Zealand | 0.5 | 0.5 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 4.1 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.2 |
| Non-OECD | **27.6** | **27.1** | **25.3** | **26.3** | **27.2** | **29.4** | **32.0** | **0.6** |
| Non-OECD Europe and Eurasia | **12.8** | **12.9** | **11.2** | **11.3** | **11.6** | **12.9** | **14.2** | **0.3** |
| Russia | **9.8** | **9.9** | **8.3** | **8.3** | **8.0** | **8.6** | **9.1** | **-0.3** |
| Caspian Area | **2.8** | **2.7** | **2.7** | **2.9** | **3.5** | **4.1** | **5.0** | **2.2** |
| Kazakhstan | 1.6 | 1.5 | 1.6 | 1.8 | 2.4 | 3.0 | 3.9 | 3.4 |
| Other | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | -0.3 |
| Other | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **-1.3** |
| Non-OECD Asia | **7.2** | **7.2** | **7.2** | **7.0** | **6.8** | **6.8** | **6.7** | **-0.3** |
| China | 4.1 | 4.1 | 4.2 | 4.3 | 4.2 | 4.4 | 4.4 | 0.3 |
| India | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | -0.4 |
| Other | 2.4 | 2.4 | 2.2 | 2.0 | 1.9 | 1.7 | 1.6 | -1.4 |
| Middle East (Non-OPEC) | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.7** | **0.7** | **-2.3** |
| Africa | **2.2** | **1.9** | **1.9** | **2.0** | **2.1** | **2.2** | **2.3** | **0.8** |
| Non-OECD Americas | **3.9** | **3.8** | **4.2** | **5.1** | **5.9** | **6.7** | **8.2** | **2.7** |
| Brazil | 2.1 | 2.1 | 2.4 | 3.0 | 3.4 | 3.7 | 4.4 | 2.7 |
| Other | 1.8 | 1.8 | 1.8 | 2.1 | 2.5 | 3.1 | 3.8 | 2.8 |
| Total World | **74.7** | **76.2** | **78.5** | **81.2** | **83.9** | **87.6** | **92.2** | **0.7** |
| OPEC share of world production | 43% | 44% | 39% | 38% | 39% | 38% | 37% | |
| Persian Gulf share of world production | 31% | 30% | 29% | 28% | 29% | 29% | 28% | |

[a]Crude oil production also includes tight oil, shale oil, extra-heavy oil, field condensate, and bitumen.
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_HighPriceCase-IEO.xlsm]A5. Crude & LC Production.

## Table G6. World other liquid fuels[a] production by region and country, High Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **3.7** | **3.8** | **4.6** | **4.9** | **5.3** | **5.8** | **5.9** | **1.6** |
| Natural gas plant liquids | 3.6 | 3.7 | 4.3 | 4.6 | 4.9 | 5.3 | 5.3 | 1.3 |
| Liquids from renewable sources[c] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from natural gas | 0.1 | 0.1 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 6.9 |
| Refinery gain | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | |
| **Non-OPEC** | **9.9** | **10.2** | **13.7** | **15.1** | **16.6** | **18.4** | **20.3** | **2.5** |
| **OECD** | **6.6** | **6.8** | **9.2** | **9.6** | **10.0** | **10.6** | **11.1** | **1.8** |
| Natural gas plant liquids | 3.6 | 3.8 | 5.7 | 6.0 | 6.0 | 6.1 | 5.9 | 1.6 |
| Liquids from renewable sources[c] | 1.3 | 1.3 | 1.5 | 1.5 | 1.6 | 1.7 | 1.9 | 1.4 |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.7 | 26.4 |
| Liquids from natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.5 | — |
| Liquids from kerogen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| Refinery processing gain | 1.7 | 1.7 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 0.8 |
| **Non-OECD** | **3.3** | **3.4** | **4.5** | **5.5** | **6.7** | **7.8** | **9.2** | **3.6** |
| Natural gas plant liquids | 1.8 | 1.8 | 2.4 | 2.7 | 3.1 | 3.4 | 4.0 | 2.8 |
| Liquids from renewable sources[c] | 0.6 | 0.7 | 1.0 | 1.3 | 1.7 | 2.1 | 2.4 | 4.7 |
| Liquids from coal | 0.2 | 0.2 | 0.3 | 0.3 | 0.6 | 0.9 | 1.2 | 6.7 |
| Liquids from natural gas | 0.1 | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 8.8 |
| Refinery gain | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 2.1 |
| **Total World** | **13.7** | **14.0** | **18.4** | **20.0** | **22.0** | **24.2** | **26.3** | **2.3** |
| **Natural gas plant liquids** | **9.0** | **9.4** | **12.4** | **13.4** | **14.0** | **14.8** | **15.2** | **1.7** |
| United States | 2.2 | 2.4 | 4.3 | 4.6 | 4.6 | 4.7 | 4.6 | 2.3 |
| Russia | 0.6 | 0.6 | 0.9 | 1.1 | 1.3 | 1.6 | 2.0 | 4.2 |
| **Liquids from renewable sources[c]** | **1.9** | **1.9** | **2.5** | **2.9** | **3.3** | **3.7** | **4.2** | **2.9** |
| Brazil | 0.4 | 0.4 | 0.6 | 0.8 | 1.0 | 1.1 | 1.2 | 3.9 |
| China | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 9.9 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 5.8 |
| United States | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 | 1.0 |
| **Liquids from coal** | **0.2** | **0.2** | **0.3** | **0.4** | **0.9** | **1.4** | **1.9** | **8.5** |
| Australia and New Zealand | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| China | 0.0 | 0.0 | 0.1 | 0.3 | 0.6 | 0.9 | 1.2 | 13.7 |
| Germany | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| South Africa | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| United States | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.7 | — |
| **Liquids from natural gas** | **0.1** | **0.1** | **0.3** | **0.5** | **0.7** | **1.1** | **1.5** | **9.0** |
| Qatar | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.6 | 6.5 |
| South Africa | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.3 | 0.4 | 10.0 |
| **Refinery processing gain** | **2.4** | **2.4** | **2.8** | **2.8** | **3.0** | **3.2** | **3.4** | **1.2** |
| United States | 1.1 | 1.1 | 1.4 | 1.3 | 1.3 | 1.3 | 1.4 | 0.9 |
| China | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 2.3 |

[a]Other liquid fuels include natural gas plant liquids, liquids from renewable sources (biofuels, including ethanol, biodiesel, and biomass-to-liquids [BTL]), liquids from natural gas (gas-to-liquids [GTL]), liquids from coal (coal-to-liquids [CTL]), and liquids from kerogen (oil shale).
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
[c]Liquids from renewable sources (biofuels) include ethanol, biodiesel, and biomass-to-liquids (BTL). All values, including ethanol, are reported on a volume basis.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_HighPriceCase-IEO.xlsm]A6. Other Liquids.

## Table G7. World petroleum and other liquids production by region and country, Low Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[a]** | **36.0** | **37.4** | **43.2** | **45.6** | **49.9** | **54.7** | **59.4** | **1.7** |
| Middle East | 26.2 | 26.6 | 31.1 | 32.3 | 35.5 | 39.2 | 42.0 | 1.7 |
| North Africa | 2.4 | 3.3 | 3.4 | 3.6 | 3.7 | 3.9 | 4.2 | 0.8 |
| West Africa | 4.3 | 4.3 | 4.5 | 4.7 | 5.0 | 5.6 | 6.4 | 1.4 |
| South America | 3.2 | 3.2 | 4.1 | 5.0 | 5.5 | 5.9 | 6.8 | 2.7 |
| Non-OPEC | **52.4** | **53.0** | **59.5** | **61.0** | **61.5** | **62.2** | **63.5** | **0.6** |
| OECD | **21.6** | **22.5** | **27.9** | **27.1** | **26.0** | **24.9** | **24.3** | **0.3** |
| OECD Americas | **16.7** | **17.9** | **23.7** | **23.1** | **22.2** | **21.3** | **20.9** | **0.5** |
| United States | 10.1 | 11.1 | 16.1 | 15.7 | 14.9 | 13.9 | 13.1 | 0.6 |
| Canada | 3.6 | 3.9 | 5.1 | 4.8 | 4.7 | 4.6 | 4.6 | 0.7 |
| Mexico and Chile | 3.0 | 3.0 | 2.5 | 2.5 | 2.6 | 2.8 | 3.2 | 0.2 |
| OECD Europe | **4.1** | **3.8** | **3.4** | **3.2** | **3.0** | **2.9** | **2.8** | **-1.1** |
| North Sea | 3.3 | 3.0 | 2.4 | 2.3 | 2.1 | 1.9 | 1.8 | -1.8 |
| Other | 0.8 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.7 |
| OECD Asia | **0.8** | **0.8** | **0.8** | **0.8** | **0.7** | **0.7** | **0.7** | **-0.4** |
| Australia and New Zealand | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | -0.1 |
| Other | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -1.0 |
| Non-OECD | **30.9** | **30.5** | **31.6** | **34.0** | **35.5** | **37.3** | **39.1** | **0.9** |
| Non-OECD Europe and Eurasia | **13.7** | **13.8** | **13.8** | **15.2** | **16.1** | **16.9** | **17.7** | **0.9** |
| Russia | **10.4** | **10.6** | **10.1** | **10.8** | **11.3** | **11.9** | **12.6** | **0.6** |
| Caspian Area | **3.0** | **2.9** | **3.4** | **4.2** | **4.6** | **4.8** | **4.9** | **1.9** |
| Kazakhstan | 1.6 | 1.6 | 2.3 | 3.0 | 3.4 | 3.6 | 3.7 | 3.1 |
| Other | 1.3 | 1.3 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | -0.3 |
| Other | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.2** | **0.2** | **-0.9** |
| Non-OECD Asia | **8.2** | **8.3** | **8.8** | **9.0** | **9.0** | **9.3** | **9.4** | **0.5** |
| China | 4.4 | 4.4 | 4.8 | 5.1 | 5.3 | 5.6 | 5.8 | 1.0 |
| India | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 0.8 |
| Other | 2.8 | 2.9 | 2.8 | 2.6 | 2.5 | 2.4 | 2.4 | -0.7 |
| Middle East (Non-OPEC) | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.8** | **0.7** | **-2.2** |
| Oman | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | -2.1 |
| Other | 0.6 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -2.5 |
| Africa | **2.6** | **2.3** | **2.4** | **2.3** | **2.5** | **2.5** | **2.6** | **0.4** |
| Ghana | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 2.9 |
| Other | 2.5 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 0.3 |
| Non-OECD Americas | **4.8** | **4.8** | **5.6** | **6.5** | **7.1** | **7.8** | **8.7** | **2.2** |
| Brazil | 2.7 | 2.7 | 3.5 | 4.4 | 5.0 | 5.7 | 6.5 | 3.3 |
| Other | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 0.1 |
| Total World | **88.5** | **90.4** | **102.6** | **106.7** | **111.4** | **116.9** | **122.8** | **1.1** |
| OPEC share of world production | 41% | 41% | 42% | 43% | 45% | 47% | 48% | |
| Persian Gulf share of world production | 30% | 29% | 30% | 30% | 32% | 34% | 34% | |

[a]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_LowPriceCase-IEO.xlsm]A4. Petroleum & Other Liquids.

## Table G8. World crude oil[a] production by region and country, Low Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **32.2** | **33.4** | **38.9** | **41.1** | **45.3** | **49.7** | **54.5** | **1.8** |
| Middle East | 22.9 | 23.2 | 27.8 | 28.9 | 32.2 | 35.6 | 38.5 | 1.8 |
| North Africa | 2.0 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.3 | 0.5 |
| West Africa | 4.3 | 4.3 | 4.4 | 4.5 | 4.9 | 5.5 | 6.3 | 1.3 |
| South America | 3.0 | 3.0 | 3.8 | 4.7 | 5.1 | 5.6 | 6.5 | 2.8 |
| **Non-OPEC** | **42.5** | **42.8** | **46.7** | **47.7** | **47.6** | **47.8** | **48.4** | **0.4** |
| **OECD** | **14.9** | **15.7** | **19.3** | **18.4** | **17.3** | **16.3** | **15.7** | **0.0** |
| **OECD Americas** | **11.2** | **12.2** | **16.4** | **15.8** | **14.9** | **14.1** | **13.8** | **0.4** |
| United States | 5.7 | 6.5 | 9.9 | 9.5 | 8.7 | 7.8 | 7.1 | 0.3 |
| Canada | 2.9 | 3.1 | 4.4 | 4.1 | 3.9 | 3.9 | 3.9 | 0.8 |
| Mexico and Chile | 2.6 | 2.6 | 2.1 | 2.2 | 2.3 | 2.5 | 2.8 | 0.3 |
| **OECD Europe** | **3.3** | **3.0** | **2.3** | **2.1** | **1.9** | **1.7** | **1.5** | **-2.4** |
| North Sea | 2.8 | 2.5 | 2.0 | 1.8 | 1.6 | 1.5 | 1.3 | -2.3 |
| Other | 0.5 | 0.5 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | -3.0 |
| **OECD Asia** | **0.5** | **0.5** | **0.5** | **0.5** | **0.5** | **0.4** | **0.4** | **-0.3** |
| Australia and New Zealand | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | -0.3 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -1.2 |
| **Non-OECD** | **27.6** | **27.1** | **27.4** | **29.3** | **30.3** | **31.5** | **32.7** | **0.7** |
| **Non-OECD Europe and Eurasia** | **12.8** | **12.9** | **12.9** | **14.2** | **14.9** | **15.4** | **15.8** | **0.7** |
| **Russia** | **9.8** | **9.9** | **9.5** | **10.1** | **10.5** | **10.9** | **11.3** | **0.5** |
| **Caspian Area** | **2.8** | **2.7** | **3.2** | **3.9** | **4.2** | **4.4** | **4.3** | **1.7** |
| Kazakhstan | 1.6 | 1.5 | 2.1 | 2.8 | 3.1 | 3.3 | 3.2 | 2.7 |
| Other | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | -0.3 |
| **Other** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **0.2** | **-1.3** |
| **Non-OECD Asia** | **7.2** | **7.2** | **7.3** | **7.2** | **7.0** | **7.1** | **7.1** | **-0.1** |
| China | 4.1 | 4.1 | 4.3 | 4.4 | 4.5 | 4.7 | 4.8 | 0.6 |
| India | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | -0.4 |
| Other | 2.4 | 2.4 | 2.2 | 2.0 | 1.9 | 1.7 | 1.6 | -1.4 |
| **Middle East (Non-OPEC)** | **1.5** | **1.3** | **1.0** | **0.9** | **0.8** | **0.7** | **0.7** | **-2.3** |
| **Africa** | **2.2** | **1.9** | **1.9** | **2.0** | **2.2** | **2.2** | **2.3** | **0.7** |
| **Non-OECD Americas** | **3.9** | **3.8** | **4.4** | **5.1** | **5.5** | **6.1** | **6.9** | **2.1** |
| Brazil | 2.1 | 2.1 | 2.7 | 3.4 | 3.9 | 4.4 | 5.2 | 3.3 |
| Other | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.7 | -0.1 |
| **Total World** | **74.7** | **76.2** | **85.6** | **88.8** | **92.9** | **97.6** | **102.9** | **1.1** |
| OPEC share of world production | 43% | 44% | 45% | 46% | 49% | 51% | 53% | |
| Persian Gulf share of world production | 31% | 30% | 33% | 33% | 35% | 37% | 37% | |

[a]Crude oil production also includes tight oil, shale oil, extra-heavy oil, field condensate, and bitumen.
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_LowPriceCase-IEO.xlsm]A5. Crude & LC Production.

## Table G9. World other liquid fuels[a] production by region and country, Low Oil Price case, 2011–40
(million barrels per day, unless otherwise noted)

| Region/country | History (estimates) 2011 | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| **OPEC[b]** | **3.7** | **3.8** | **4.3** | **4.5** | **4.5** | **4.9** | **4.8** | **0.8** |
| Natural gas plant liquids | 3.6 | 3.7 | 4.0 | 4.2 | 4.4 | 4.8 | 4.7 | 0.8 |
| Liquids from renewable sources[c] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from natural gas | 0.1 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 |
| Refinery gain | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | — |
| **Non-OPEC** | **9.9** | **10.2** | **12.8** | **13.3** | **13.9** | **14.4** | **15.0** | **1.4** |
| **OECD** | **6.6** | **6.8** | **8.6** | **8.7** | **8.8** | **8.7** | **8.6** | **0.9** |
| Natural gas plant liquids | 3.6 | 3.8 | 5.3 | 5.3 | 5.3 | 5.2 | 5.0 | 1.0 |
| Liquids from renewable sources[c] | 1.3 | 1.3 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 0.9 |
| Liquids from coal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from natural gas | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Liquids from kerogen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| Refinery processing gain | 1.7 | 1.7 | 1.8 | 1.9 | 1.9 | 1.9 | 2.0 | 0.5 |
| **Non-OECD** | **3.3** | **3.4** | **4.1** | **4.6** | **5.2** | **5.8** | **6.4** | **2.3** |
| Natural gas plant liquids | 1.8 | 1.8 | 2.1 | 2.4 | 2.6 | 2.9 | 3.3 | 2.1 |
| Liquids from renewable sources[c] | 0.6 | 0.7 | 0.9 | 1.1 | 1.4 | 1.7 | 1.9 | 3.9 |
| Liquids from coal | 0.2 | 0.2 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | — |
| Liquids from natural gas | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -3.8 |
| Refinery gain | 0.6 | 0.7 | 0.9 | 1.0 | 1.1 | 1.2 | 1.2 | 2.2 |
| **Total World** | **13.7** | **14.0** | **17.1** | **17.9** | **18.5** | **19.3** | **19.9** | **1.3** |
| **Natural gas plant liquids** | **9.0** | **9.4** | **11.3** | **11.9** | **12.3** | **12.8** | **13.0** | **1.2** |
| United States | 2.2 | 2.4 | 3.9 | 4.0 | 4.0 | 3.9 | 3.7 | 1.5 |
| Russia | 0.6 | 0.6 | 0.6 | 0.7 | 0.8 | 1.0 | 1.2 | 2.3 |
| **Liquids from renewable sources[c]** | **1.9** | **1.9** | **2.4** | **2.7** | **3.0** | **3.3** | **3.5** | **2.2** |
| Brazil | 0.4 | 0.4 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 | 3.1 |
| China | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 9.0 |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 5.8 |
| United States | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.4 |
| **Liquids from coal** | **0.2** | **0.2** | **0.3** | **0.1** | **0.0** | **0.0** | **0.0** | **—** |
| Australia and New Zealand | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| China | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | — |
| Germany | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| India | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| South Africa | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| United States | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| **Liquids from natural gas** | **0.1** | **0.1** | **0.3** | **0.3** | **0.1** | **0.1** | **0.1** | **-0.5** |
| Qatar | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.3 |
| South Africa | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| **Refinery processing gain** | **2.4** | **2.4** | **2.8** | **2.9** | **3.0** | **3.1** | **3.2** | **1.0** |
| United States | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 0.7 |
| China | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 2.4 |

[a]Other liquid fuels include natural gas plant liquids, liquids from renewable sources (biofuels, including ethanol, biodiesel, and biomass-to-liquids [BTL]), liquids from natural gas (gas-to-liquids [GTL]), liquids from coal (coal-to-liquids [CTL]), and liquids from kerogen (oil shale).
[b]OPEC=Organization of the Petroleum Exporting Countries (OPEC-12). Indonesia reactivated its OPEC membership on January 1, 2016, but this is not reflected in the IEO2016 projections. Indonesia is reported as part of non-OPEC, non-OECD Asia.
[c]Liquids from renewable sources (biofuels) include ethanol, biodiesel, and biomass-to-liquids (BTL). All values, including ethanol, are reported on a volume basis.
Notes: Totals may not equal sum of components due to independent rounding.
Source File: \\nem6\D\IEO2015_GWOB\Final_Files\[GWOB_HighPriceCase-IEO.xlsm]A6. Other Liquids.

Appendix H

# Reference case projections for electricity capacity and generation by fuel

## Table H1. World total installed generating capacity by region and country, 2011–40 (gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **1,258** | **1,278** | **1,330** | **1,371** | **1,436** | **1,517** | **1,622** | **0.9** |
| United States[a] | 1,046 | 1,063 | 1,079 | 1,091 | 1,133 | 1,187 | 1,261 | 0.6 |
| Canada | 133 | 135 | 154 | 165 | 176 | 190 | 204 | 1.5 |
| Mexico and Chile | 79 | 80 | 97 | 115 | 127 | 140 | 156 | 2.4 |
| **OECD Europe** | **944** | **985** | **1,128** | **1,148** | **1,179** | **1,227** | **1,276** | **0.9** |
| **OECD Asia** | **412** | **428** | **490** | **516** | **536** | **553** | **569** | **1.0** |
| Japan | 261 | 267 | 282 | 295 | 299 | 300 | 295 | 0.4 |
| South Korea | 80 | 90 | 124 | 132 | 142 | 150 | 159 | 2.1 |
| Australia and New Zealand | 71 | 72 | 84 | 89 | 95 | 103 | 115 | 1.7 |
| **Total OECD** | **2,614** | **2,691** | **2,949** | **3,035** | **3,152** | **3,297** | **3,467** | **0.9** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **411** | **418** | **462** | **468** | **480** | **494** | **499** | **0.6** |
| Russia | 230 | 233 | 267 | 267 | 272 | 277 | 275 | 0.6 |
| Other | 180 | 185 | 194 | 201 | 208 | 217 | 225 | 0.7 |
| **Non-OECD Asia** | **1,584** | **1,708** | **2,383** | **2,612** | **2,840** | **3,079** | **3,332** | **2.4** |
| China | 1,065 | 1,153 | 1,657 | 1,808 | 1,937 | 2,066 | 2,194 | 2.3 |
| India | 238 | 255 | 347 | 396 | 459 | 527 | 607 | 3.1 |
| Other | 281 | 300 | 379 | 408 | 444 | 486 | 531 | 2.1 |
| **Middle East** | **204** | **220** | **287** | **333** | **363** | **403** | **434** | **2.5** |
| **Africa** | **135** | **141** | **191** | **202** | **232** | **266** | **306** | **2.8** |
| **Non-OECD Americas** | **252** | **261** | **305** | **329** | **357** | **386** | **418** | **1.7** |
| Brazil | 119 | 122 | 148 | 162 | 180 | 197 | 216 | 2.1 |
| Other | 133 | 139 | 157 | 167 | 177 | 189 | 202 | 1.3 |
| **Total Non-OECD** | **2,587** | **2,748** | **3,628** | **3,946** | **4,271** | **4,627** | **4,988** | **2.2** |
| **Total World** | **5,202** | **5,440** | **6,577** | **6,981** | **7,422** | **7,925** | **8,455** | **1.6** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H2. World installed liquids-fired generating capacity by region and country, 2011–40 (gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **125** | **121** | **108** | **98** | **92** | **87** | **85** | **-1.2** |
| United States[a] | 105 | 101 | 89 | 80 | 75 | 71 | 70 | -1.3 |
| Canada | 4 | 4 | 4 | 4 | 4 | 4 | 3 | -1.0 |
| Mexico and Chile | 16 | 16 | 14 | 14 | 13 | 12 | 12 | -1.0 |
| OECD Europe | **50** | **50** | **47** | **45** | **43** | **41** | **39** | **-0.9** |
| OECD Asia | **58** | **59** | **54** | **52** | **49** | **47** | **45** | **-1.0** |
| Japan | 52 | 52 | 49 | 46 | 44 | 42 | 40 | -1.0 |
| South Korea | 4 | 5 | 4 | 4 | 4 | 4 | 4 | -1.0 |
| Australia and New Zealand | 1 | 2 | 2 | 1 | 1 | 1 | 1 | -0.6 |
| Total OECD | **234** | **229** | **210** | **195** | **184** | **175** | **169** | **-1.1** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **20** | **21** | **20** | **19** | **18** | **17** | **17** | **-0.8** |
| Russia | 3 | 3 | 4 | 4 | 4 | 3 | 3 | -0.1 |
| Other | 17 | 17 | 16 | 15 | 15 | 14 | 13 | -1.0 |
| Non-OECD Asia | **56** | **56** | **55** | **53** | **50** | **48** | **46** | **-0.7** |
| China | 8 | 8 | 8 | 7 | 7 | 7 | 6 | -0.9 |
| India | 8 | 7 | 7 | 7 | 7 | 7 | 6 | -0.5 |
| Other | 40 | 41 | 40 | 38 | 36 | 35 | 33 | -0.7 |
| Middle East | **37** | **39** | **53** | **51** | **50** | **48** | **46** | **0.6** |
| Africa | **15** | **15** | **16** | **15** | **15** | **14** | **13** | **-0.5** |
| Non-OECD Americas | **32** | **34** | **34** | **33** | **31** | **30** | **29** | **-0.6** |
| Brazil | 7 | 8 | 8 | 7 | 7 | 7 | 6 | -0.6 |
| Other | 25 | 26 | 26 | 25 | 24 | 23 | 22 | -0.6 |
| Total Non-OECD | **161** | **165** | **178** | **171** | **164** | **157** | **151** | **-0.3** |
| Total World | **394** | **395** | **388** | **366** | **348** | **332** | **320** | **-0.8** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H3. World installed natural-gas-fired generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **410** | **420** | **455** | **488** | **534** | **584** | **640** | **1.5** |
| United States[a] | 358 | 367 | 393 | 409 | 444 | 481 | 525 | 1.3 |
| Canada | 20 | 20 | 25 | 30 | 36 | 41 | 46 | 3.0 |
| Mexico and Chile | 32 | 32 | 38 | 49 | 54 | 62 | 69 | 2.7 |
| **OECD Europe** | **238** | **244** | **244** | **249** | **264** | **278** | **308** | **0.8** |
| **OECD Asia** | **129** | **136** | **148** | **158** | **165** | **179** | **194** | **1.3** |
| Japan | 83 | 86 | 89 | 96 | 97 | 101 | 104 | 0.7 |
| South Korea | 26 | 30 | 37 | 37 | 39 | 44 | 49 | 1.8 |
| Australia and New Zealand | 20 | 21 | 22 | 25 | 29 | 34 | 41 | 2.4 |
| **Total OECD** | **777** | **799** | **848** | **895** | **963** | **1,040** | **1,142** | **1.3** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **147** | **151** | **165** | **167** | **176** | **184** | **187** | **0.8** |
| Russia | 107 | 109 | 118 | 113 | 116 | 119 | 117 | 0.3 |
| Other | 40 | 42 | 47 | 54 | 59 | 65 | 70 | 1.8 |
| **Non-OECD Asia** | **180** | **186** | **234** | **277** | **315** | **375** | **426** | **3.0** |
| China | 39 | 41 | 74 | 107 | 124 | 156 | 186 | 5.5 |
| India | 25 | 24 | 25 | 27 | 31 | 40 | 45 | 2.2 |
| Other | 116 | 121 | 135 | 143 | 160 | 179 | 195 | 1.7 |
| **Middle East** | **153** | **165** | **201** | **221** | **241** | **253** | **272** | **1.8** |
| **Africa** | **55** | **59** | **74** | **78** | **94** | **115** | **137** | **3.1** |
| **Non-OECD Americas** | **58** | **62** | **75** | **79** | **81** | **85** | **88** | **1.3** |
| Brazil | 12 | 11 | 17 | 17 | 17 | 17 | 17 | 1.4 |
| Other | 46 | 51 | 58 | 62 | 65 | 68 | 72 | 1.2 |
| **Total Non-OECD** | **593** | **624** | **749** | **822** | **908** | **1,012** | **1,111** | **2.1** |
| Total World | **1,370** | **1,423** | **1,597** | **1,717** | **1,870** | **2,052** | **2,252** | **1.7** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H4. World installed coal-fired generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **333** | **327** | **279** | **276** | **272** | **272** | **271** | **-0.7** |
| United States[a] | 314 | 308 | 263 | 260 | 260 | 260 | 260 | -0.6 |
| Canada | 10 | 10 | 7 | 7 | 3 | 3 | 2 | -5.2 |
| Mexico and Chile | 9 | 9 | 9 | 9 | 9 | 9 | 9 | -0.2 |
| OECD Europe | **197** | **198** | **207** | **200** | **194** | **188** | **183** | **-0.3** |
| OECD Asia | **109** | **112** | **117** | **113** | **111** | **109** | **110** | **-0.1** |
| Japan | 50 | 50 | 49 | 47 | 46 | 44 | 43 | -0.6 |
| South Korea | 28 | 31 | 39 | 38 | 38 | 39 | 41 | 1.0 |
| Australia and New Zealand | 31 | 30 | 29 | 28 | 27 | 26 | 26 | -0.5 |
| Total OECD | **639** | **637** | **603** | **590** | **577** | **570** | **564** | **-0.4** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **111** | **110** | **112** | **109** | **110** | **112** | **111** | **0.0** |
| Russia | 49 | 49 | 53 | 51 | 54 | 56 | 56 | 0.5 |
| Other | 62 | 61 | 59 | 58 | 57 | 55 | 55 | -0.4 |
| Non-OECD Asia | **922** | **993** | **1,178** | **1,195** | **1,194** | **1,208** | **1,235** | **0.8** |
| China | 719 | 770 | 888 | 901 | 886 | 865 | 845 | 0.3 |
| India | 139 | 153 | 188 | 189 | 197 | 222 | 255 | 1.8 |
| Other | 65 | 71 | 102 | 105 | 112 | 121 | 136 | 2.4 |
| Middle East | **0** | **0** | **1** | **1** | **1** | **1** | **1** | **6.4** |
| Africa | **36** | **36** | **46** | **45** | **46** | **47** | **51** | **1.3** |
| Non-OECD Americas | **6** | **6** | **8** | **8** | **8** | **8** | **8** | **0.8** |
| Brazil | 3 | 4 | 5 | 5 | 5 | 4 | 4 | 0.6 |
| Other | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 1.1 |
| Total Non-OECD | **1,076** | **1,146** | **1,344** | **1,358** | **1,359** | **1,376** | **1,406** | **0.7** |
| Total World | **1,715** | **1,782** | **1,947** | **1,947** | **1,936** | **1,946** | **1,970** | **0.4** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H5. World installed nuclear generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **115** | **117** | **115** | **113** | **115** | **114** | **118** | **0.0** |
| United States[a] | 102 | 102 | 101 | 101 | 102 | 102 | 105 | 0.1 |
| Canada | 13 | 14 | 12 | 10 | 10 | 10 | 9 | -1.5 |
| Mexico and Chile | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 3.2 |
| OECD Europe | **123** | **122** | **116** | **120** | **126** | **127** | **120** | **-0.1** |
| OECD Asia | **63** | **65** | **56** | **63** | **66** | **64** | **60** | **-0.3** |
| Japan | 44 | 44 | 28 | 31 | 30 | 29 | 25 | -2.0 |
| South Korea | 19 | 21 | 27 | 33 | 36 | 36 | 36 | 2.0 |
| Australia and New Zealand | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Total OECD | **301** | **304** | **287** | **297** | **306** | **306** | **298** | **-0.1** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **40** | **40** | **53** | **59** | **58** | **58** | **58** | **1.3** |
| Russia | 24 | 24 | 33 | 38 | 34 | 33 | 32 | 1.1 |
| Other | 17 | 17 | 20 | 21 | 24 | 25 | 26 | 1.6 |
| Non-OECD Asia | **22** | **23** | **61** | **89** | **141** | **173** | **206** | **8.2** |
| China | 12 | 13 | 41 | 57 | 95 | 123 | 152 | 9.2 |
| India | 4 | 4 | 11 | 19 | 34 | 36 | 41 | 8.3 |
| Other | 6 | 6 | 9 | 13 | 13 | 13 | 14 | 3.2 |
| Middle East | **1** | **1** | **6** | **9** | **14** | **19** | **22** | **12.1** |
| Africa | **2** | **2** | **2** | **3** | **4** | **5** | **6** | **4.0** |
| Non-OECD Americas | **3** | **3** | **5** | **5** | **10** | **11** | **12** | **5.3** |
| Brazil | 2 | 2 | 3 | 3 | 7 | 7 | 7 | 5.0 |
| Other | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 5.9 |
| Total Non-OECD | **68** | **69** | **127** | **164** | **227** | **265** | **304** | **5.4** |
| Total World | **369** | **373** | **414** | **461** | **532** | **570** | **602** | **1.7** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H6. World installed hydroelectric and other renewable generating capacity by region and country, 2011–40 (gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **273** | **293** | **372** | **396** | **424** | **460** | **507** | **2.0** |
| United States[a] | 168 | 185 | 233 | 240 | 252 | 273 | 301 | 1.8 |
| Canada | 85 | 87 | 106 | 114 | 123 | 132 | 144 | 1.8 |
| Mexico and Chile | 20 | 21 | 34 | 42 | 48 | 55 | 62 | 3.9 |
| **OECD Europe** | **337** | **372** | **514** | **534** | **553** | **594** | **626** | **1.9** |
| **OECD Asia** | **54** | **57** | **115** | **129** | **145** | **153** | **161** | **3.8** |
| Japan | 32 | 33 | 66 | 74 | 82 | 84 | 84 | 3.3 |
| South Korea | 3 | 4 | 16 | 21 | 26 | 28 | 30 | 7.8 |
| Australia and New Zealand | 19 | 20 | 32 | 34 | 37 | 41 | 47 | 3.2 |
| **Total OECD** | **664** | **721** | **1,001** | **1,059** | **1,122** | **1,207** | **1,294** | **2.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **92** | **95** | **112** | **114** | **117** | **124** | **127** | **1.0** |
| Russia | 47 | 48 | 59 | 61 | 64 | 66 | 66 | 1.1 |
| Other | 44 | 47 | 53 | 53 | 54 | 57 | 60 | 0.9 |
| **Non-OECD Asia** | **404** | **449** | **854** | **999** | **1,139** | **1,275** | **1,418** | **4.2** |
| China | 287 | 321 | 647 | 736 | 825 | 915 | 1,004 | 4.2 |
| India | 62 | 66 | 115 | 154 | 191 | 223 | 261 | 5.0 |
| Other | 55 | 62 | 92 | 109 | 122 | 138 | 154 | 3.3 |
| **Middle East** | **13** | **15** | **27** | **51** | **57** | **82** | **92** | **6.7** |
| **Africa** | **27** | **29** | **54** | **61** | **74** | **85** | **99** | **4.5** |
| **Non-OECD Americas** | **153** | **156** | **183** | **205** | **226** | **252** | **281** | **2.1** |
| Brazil | 95 | 97 | 116 | 130 | 144 | 162 | 181 | 2.3 |
| Other | 58 | 59 | 67 | 75 | 82 | 91 | 100 | 1.9 |
| **Total Non-OECD** | **690** | **745** | **1,230** | **1,431** | **1,613** | **1,818** | **2,017** | **3.6** |
| **Total World** | **1,353** | **1,466** | **2,231** | **2,491** | **2,736** | **3,025** | **3,311** | **3.0** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table H7. World installed hydroelectric generating capacity by region and country, 2011–40**
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **171** | **171** | **183** | **187** | **192** | **198** | **210** | **0.7** |
| United States[a] | 78 | 78 | 80 | 80 | 80 | 80 | 80 | 0.1 |
| Canada | 75 | 75 | 83 | 85 | 88 | 90 | 99 | 1.0 |
| Mexico and Chile | 18 | 18 | 20 | 22 | 24 | 27 | 30 | 2.0 |
| **OECD Europe** | **153** | **155** | **168** | **174** | **174** | **174** | **183** | **0.6** |
| **OECD Asia** | **37** | **37** | **38** | **39** | **40** | **41** | **43** | **0.5** |
| Japan | 22 | 22 | 23 | 23 | 23 | 23 | 23 | 0.1 |
| South Korea | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0.3 |
| Australia and New Zealand | 13 | 13 | 13 | 14 | 15 | 17 | 19 | 1.2 |
| **Total OECD** | **361** | **364** | **389** | **400** | **405** | **413** | **436** | **0.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **89** | **89** | **95** | **97** | **99** | **104** | **107** | **0.7** |
| Russia | 47 | 47 | 51 | 53 | 55 | 57 | 57 | 0.7 |
| Other | 41 | 42 | 44 | 44 | 44 | 47 | 50 | 0.6 |
| **Non-OECD Asia** | **322** | **345** | **487** | **515** | **536** | **571** | **609** | **2.1** |
| China | 231 | 249 | 347 | 357 | 367 | 377 | 387 | 1.6 |
| India | 42 | 43 | 67 | 78 | 87 | 102 | 120 | 3.7 |
| Other | 49 | 53 | 73 | 80 | 82 | 92 | 102 | 2.4 |
| **Middle East** | **13** | **14** | **17** | **17** | **17** | **18** | **19** | **1.0** |
| **Africa** | **25** | **27** | **37** | **43** | **45** | **51** | **60** | **3.0** |
| **Non-OECD Americas** | **139** | **141** | **155** | **175** | **194** | **217** | **242** | **2.0** |
| Brazil | 82 | 84 | 96 | 109 | 121 | 136 | 153 | 2.2 |
| Other | 56 | 57 | 59 | 66 | 73 | 80 | 89 | 1.6 |
| **Total Non-OECD** | **588** | **615** | **789** | **846** | **890** | **961** | **1,037** | **1.9** |
| **Total World** | **949** | **979** | **1,178** | **1,245** | **1,296** | **1,373** | **1,473** | **1.5** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H8. World installed wind-powered generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **53** | **67** | **107** | **117** | **127** | **141** | **159** | **3.1** |
| United States[a] | 47 | 59 | 83 | 84 | 87 | 97 | 110 | 2.2 |
| Canada | 5 | 6 | 15 | 18 | 20 | 22 | 24 | 5.0 |
| Mexico and Chile | 1 | 2 | 9 | 16 | 19 | 22 | 25 | 10.1 |
| **OECD Europe** | **94** | **107** | **189** | **203** | **222** | **263** | **277** | **3.5** |
| **OECD Asia** | **6** | **6** | **24** | **29** | **37** | **40** | **44** | **7.2** |
| Japan | 2 | 3 | 3 | 5 | 8 | 8 | 8 | 4.1 |
| South Korea | 0 | 0 | 9 | 12 | 16 | 17 | 18 | 13.9 |
| Australia and New Zealand | 3 | 3 | 11 | 12 | 13 | 15 | 17 | 6.2 |
| **Total OECD** | **153** | **180** | **320** | **350** | **386** | **444** | **480** | **3.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **2** | **4** | **8** | **8** | **8** | **9** | **9** | **3.4** |
| Russia | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 21.7 |
| Other | 2 | 3 | 4 | 4 | 4 | 5 | 5 | 1.1 |
| **Non-OECD Asia** | **62** | **80** | **220** | **272** | **326** | **377** | **429** | **6.2** |
| China | 45 | 61 | 183 | 225 | 267 | 308 | 350 | 6.4 |
| India | 16 | 18 | 32 | 42 | 52 | 60 | 70 | 4.9 |
| Other | 1 | 1 | 4 | 5 | 7 | 8 | 9 | 8.4 |
| **Middle East** | **0** | **0** | **2** | **6** | **8** | **12** | **14** | **19.0** |
| **Africa** | **1** | **1** | **10** | **10** | **11** | **13** | **15** | **9.8** |
| **Non-OECD Americas** | **2** | **3** | **9** | **10** | **11** | **13** | **14** | **5.1** |
| Brazil | 1 | 3 | 7 | 8 | 8 | 9 | 10 | 5.2 |
| Other | 1 | 1 | 3 | 3 | 3 | 3 | 4 | 4.8 |
| **Total Non-OECD** | **67** | **89** | **248** | **306** | **365** | **423** | **480** | **6.2** |
| **Total World** | **220** | **269** | **569** | **656** | **750** | **867** | **961** | **4.7** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H9. World installed geothermal generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **3** | **3** | **5** | **7** | **9** | **10** | **11** | **4.3** |
| United States[a] | 3 | 3 | 4 | 5 | 7 | 8 | 9 | 4.6 |
| Canada | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Mexico and Chile | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3.3 |
| **OECD Europe** | **2** | **2** | **3** | **3** | **3** | **3** | **3** | **2.6** |
| **OECD Asia** | **1** | **1** | **2** | **2** | **3** | **3** | **3** | **3.6** |
| Japan | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.0 |
| South Korea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Australia and New Zealand | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 4.5 |
| **Total OECD** | **6** | **6** | **10** | **12** | **14** | **16** | **18** | **3.8** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **0** | **0** | **2** | **2** | **2** | **2** | **2** | **11.0** |
| Russia | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 11.0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| **Non-OECD Asia** | **3** | **3** | **6** | **9** | **18** | **20** | **23** | **7.2** |
| China | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.2 |
| India | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Other | 3 | 3 | 6 | 9 | 18 | 20 | 23 | 7.2 |
| **Middle East** | **0** | **0** | **1** | **2** | **2** | **3** | **3** | **—** |
| **Africa** | **0** | **0** | **2** | **3** | **4** | **5** | **6** | **12.4** |
| **Non-OECD Americas** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1.3** |
| Brazil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Other | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.3 |
| **Total Non-OECD** | **4** | **4** | **11** | **16** | **26** | **30** | **34** | **7.8** |
| **Total World** | **10** | **10** | **22** | **28** | **41** | **46** | **52** | **5.9** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H10. World installed solar generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **5** | **8** | **32** | **36** | **44** | **54** | **67** | **7.7** |
| United States[a] | 4 | 8 | 28 | 32 | 39 | 48 | 61 | 7.7 |
| Canada | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5.9 |
| Mexico and Chile | 0 | 0 | 2 | 2 | 2 | 2 | 3 | 14.4 |
| OECD Europe | **52** | **70** | **93** | **93** | **93** | **94** | **98** | **1.2** |
| OECD Asia | **7** | **9** | **45** | **51** | **57** | **59** | **60** | **6.9** |
| Japan | 5 | 7 | 38 | 43 | 48 | 49 | 49 | 7.4 |
| South Korea | 1 | 1 | 2 | 3 | 4 | 4 | 4 | 5.1 |
| Australia and New Zealand | 1 | 1 | 5 | 5 | 5 | 6 | 7 | 5.6 |
| Total OECD | **64** | **88** | **169** | **181** | **194** | **206** | **225** | **3.4** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **1** | **2** | **6** | **6** | **6** | **7** | **7** | **4.7** |
| Russia | 0 | 0 | 2 | 2 | 2 | 3 | 3 | — |
| Other | 1 | 2 | 4 | 4 | 4 | 4 | 4 | 3.0 |
| Non-OECD Asia | **4** | **5** | **104** | **144** | **183** | **215** | **247** | **14.8** |
| China | 3 | 3 | 92 | 115 | 138 | 161 | 184 | 15.4 |
| India | 0 | 1 | 10 | 26 | 41 | 49 | 58 | 14.9 |
| Other | 0 | 1 | 2 | 4 | 4 | 5 | 6 | 7.6 |
| Middle East | **0** | **0** | **6** | **24** | **27** | **45** | **51** | **27.0** |
| Africa | **0** | **0** | **5** | **5** | **12** | **14** | **16** | **15.5** |
| Non-OECD Americas | **0** | **0** | **3** | **4** | **4** | **4** | **5** | **18.1** |
| Brazil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Other | 0 | 0 | 3 | 4 | 4 | 4 | 5 | 20.3 |
| Total Non-OECD | **5** | **7** | **124** | **183** | **233** | **285** | **326** | **14.4** |
| Total World | **69** | **95** | **293** | **364** | **427** | **491** | **551** | **6.5** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H11. World installed other renewable generating capacity by region and country, 2011–40
(gigawatts)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **41** | **42** | **45** | **49** | **52** | **57** | **59** | **1.2** |
| United States[a] | 36 | 37 | 39 | 39 | 39 | 40 | 41 | 0.4 |
| Canada | 4 | 4 | 5 | 8 | 12 | 15 | 16 | 4.9 |
| Mexico and Chile | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1.6 |
| **OECD Europe** | **35** | **38** | **61** | **61** | **61** | **61** | **65** | **1.9** |
| **OECD Asia** | **3** | **3** | **6** | **8** | **10** | **10** | **11** | **4.9** |
| Japan | 2 | 2 | 2 | 3 | 4 | 4 | 4 | 3.5 |
| South Korea | 0 | 0 | 3 | 4 | 4 | 5 | 5 | 10.3 |
| Australia and New Zealand | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2.2 |
| **Total OECD** | **80** | **83** | **112** | **117** | **123** | **128** | **135** | **1.7** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **0** | **1** | **2** | **2** | **2** | **2** | **2** | **3.2** |
| Russia | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0.4 |
| Other | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 8.4 |
| **Non-OECD Asia** | **14** | **16** | **37** | **58** | **76** | **93** | **111** | **7.2** |
| China | 8 | 8 | 25 | 39 | 54 | 68 | 83 | 8.7 |
| India | 3 | 4 | 6 | 8 | 11 | 12 | 14 | 4.8 |
| Other | 2 | 4 | 7 | 11 | 12 | 13 | 14 | 4.6 |
| **Middle East** | **0** | **1** | **2** | **3** | **3** | **5** | **5** | **7.2** |
| **Africa** | **1** | **1** | **1** | **1** | **1** | **2** | **2** | **2.1** |
| **Non-OECD Americas** | **12** | **11** | **15** | **16** | **17** | **18** | **20** | **2.1** |
| Brazil | 11 | 10 | 13 | 14 | 15 | 16 | 18 | 2.0 |
| Other | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3.0 |
| **Total Non-OECD** | **26** | **30** | **57** | **80** | **99** | **120** | **140** | **5.7** |
| **Total World** | **105** | **113** | **169** | **198** | **222** | **247** | **275** | **3.2** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H12. World total net electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **5,071** | **5,017** | **5,449** | **5,724** | **6,036** | **6,359** | **6,727** | **1.1** |
| United States[a] | 4,102 | 4,055 | 4,351 | 4,513 | 4,691 | 4,860 | 5,056 | 0.8 |
| Canada | 627 | 616 | 692 | 748 | 809 | 880 | 958 | 1.6 |
| Mexico and Chile | 342 | 346 | 406 | 463 | 535 | 618 | 713 | 2.6 |
| **OECD Europe** | **3,455** | **3,483** | **3,858** | **4,090** | **4,328** | **4,590** | **4,889** | **1.2** |
| **OECD Asia** | **1,808** | **1,748** | **2,014** | **2,142** | **2,261** | **2,398** | **2,536** | **1.3** |
| Japan | 1,033 | 968 | 1,058 | 1,097 | 1,124 | 1,149 | 1,149 | 0.6 |
| South Korea | 491 | 501 | 628 | 680 | 735 | 794 | 856 | 1.9 |
| Australia and New Zealand | 284 | 279 | 328 | 364 | 402 | 455 | 530 | 2.3 |
| **Total OECD** | **10,334** | **10,248** | **11,321** | **11,956** | **12,625** | **13,347** | **14,152** | **1.2** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **1,636** | **1,650** | **1,688** | **1,823** | **1,951** | **2,081** | **2,147** | **0.9** |
| Russia | 998 | 1,013 | 1,033 | 1,095 | 1,151 | 1,206 | 1,205 | 0.6 |
| Other | 638 | 637 | 655 | 728 | 800 | 875 | 943 | 1.4 |
| **Non-OECD Asia** | **6,689** | **7,020** | **9,618** | **10,978** | **12,197** | **13,521** | **14,909** | **2.7** |
| China | 4,547 | 4,771 | 6,685 | 7,497 | 8,145 | 8,794 | 9,426 | 2.5 |
| India | 1,006 | 1,052 | 1,387 | 1,669 | 1,966 | 2,336 | 2,769 | 3.5 |
| Other | 1,135 | 1,196 | 1,546 | 1,811 | 2,086 | 2,391 | 2,714 | 3.0 |
| **Middle East** | **797** | **848** | **1,079** | **1,261** | **1,448** | **1,660** | **1,882** | **2.9** |
| **Africa** | **659** | **682** | **827** | **970** | **1,129** | **1,328** | **1,550** | **3.0** |
| **Non-OECD Americas** | **1,087** | **1,111** | **1,232** | **1,366** | **1,491** | **1,644** | **1,814** | **1.8** |
| Brazil | 530 | 538 | 615 | 694 | 770 | 863 | 966 | 2.1 |
| Other | 557 | 574 | 617 | 672 | 721 | 781 | 848 | 1.4 |
| **Total Non-OECD** | **10,867** | **11,312** | **14,444** | **16,399** | **18,215** | **20,234** | **22,302** | **2.5** |
| **Total World** | **21,201** | **21,559** | **25,765** | **28,354** | **30,840** | **33,581** | **36,454** | **1.9** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H13. World net liquids-fired electricity generation by region and country, 2011–40
(billion kilowatthours)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region/country | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012-40 |
| OECD | | | | | | | | |
| **OECD Americas** | **88** | **88** | **66** | **37** | **36** | **35** | **35** | **-3.3** |
| United States[a] | 30 | 23 | 18 | 18 | 18 | 18 | 18 | -0.9 |
| Canada | 6 | 7 | 6 | 6 | 6 | 5 | 5 | -1.0 |
| Mexico and Chile | 51 | 58 | 43 | 14 | 13 | 12 | 12 | -5.5 |
| **OECD Europe** | **65** | **75** | **71** | **68** | **65** | **62** | **59** | **-0.9** |
| **OECD Asia** | **161** | **194** | **70** | **21** | **19** | **18** | **17** | **-8.3** |
| Japan | 142 | 170 | 49 | 2 | 1 | 1 | 1 | -18.3 |
| South Korea | 16 | 20 | 17 | 16 | 15 | 14 | 13 | -1.4 |
| Australia and New Zealand | 4 | 4 | 4 | 4 | 4 | 3 | 3 | -0.6 |
| **Total OECD** | **315** | **357** | **208** | **126** | **120** | **115** | **111** | **-4.1** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **37** | **38** | **17** | **35** | **33** | **32** | **30** | **-0.8** |
| Russia | 26 | 26 | 8 | 27 | 26 | 24 | 23 | -0.4 |
| Other | 11 | 11 | 9 | 8 | 8 | 7 | 7 | -1.7 |
| **Non-OECD Asia** | **153** | **141** | **139** | **133** | **127** | **121** | **115** | **-0.7** |
| China | 8 | 6 | 6 | 6 | 6 | 5 | 5 | -0.9 |
| India | 23 | 21 | 22 | 21 | 20 | 19 | 18 | -0.6 |
| Other | 123 | 113 | 111 | 106 | 101 | 97 | 92 | -0.7 |
| **Middle East** | **288** | **307** | **274** | **185** | **137** | **131** | **125** | **-3.2** |
| **Africa** | **65** | **76** | **78** | **75** | **72** | **68** | **66** | **-0.5** |
| **Non-OECD Americas** | **134** | **138** | **141** | **134** | **128** | **123** | **117** | **-0.6** |
| Brazil | 16 | 17 | 17 | 17 | 16 | 15 | 14 | -0.6 |
| Other | 118 | 121 | 123 | 118 | 112 | 108 | 103 | -0.6 |
| **Total Non-OECD** | **677** | **699** | **648** | **562** | **497** | **475** | **453** | **-1.5** |
| **Total World** | **992** | **1,056** | **856** | **688** | **618** | **590** | **564** | **-2.2** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H14. World net natural gas-fired electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **1,234** | **1,446** | **1,396** | **1,600** | **1,840** | **2,048** | **2,237** | **1.6** |
| United States[a] | 1,014 | 1,228 | 1,117 | 1,223 | 1,371 | 1,478 | 1,569 | 0.9 |
| Canada | 61 | 63 | 97 | 136 | 187 | 230 | 272 | 5.3 |
| Mexico and Chile | 160 | 154 | 182 | 240 | 282 | 340 | 396 | 3.4 |
| **OECD Europe** | **766** | **645** | **655** | **746** | **905** | **1,056** | **1,321** | **2.6** |
| **OECD Asia** | **516** | **534** | **567** | **662** | **731** | **852** | **978** | **2.2** |
| Japan | 353 | 373 | 387 | 450 | 471 | 507 | 539 | 1.3 |
| South Korea | 109 | 105 | 111 | 112 | 128 | 172 | 213 | 2.5 |
| Australia and New Zealand | 55 | 55 | 69 | 100 | 132 | 173 | 227 | 5.2 |
| **Total OECD** | **2,516** | **2,624** | **2,618** | **3,008** | **3,477** | **3,957** | **4,537** | **2.0** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **643** | **653** | **601** | **649** | **734** | **814** | **857** | **1.0** |
| Russia | 488 | 494 | 457 | 442 | 480 | 511 | 508 | 0.1 |
| Other | 155 | 159 | 144 | 206 | 254 | 303 | 349 | 2.8 |
| **Non-OECD Asia** | **605** | **620** | **829** | **1,184** | **1,495** | **1,964** | **2,360** | **4.9** |
| China | 81 | 81 | 245 | 509 | 647 | 901 | 1,136 | 9.9 |
| India | 107 | 88 | 62 | 77 | 111 | 169 | 202 | 3.0 |
| Other | 417 | 451 | 521 | 597 | 737 | 894 | 1,021 | 3.0 |
| **Middle East** | **488** | **517** | **691** | **875** | **1,059** | **1,175** | **1,347** | **3.5** |
| **Africa** | **222** | **236** | **295** | **330** | **440** | **579** | **718** | **4.1** |
| **Non-OECD Americas** | **151** | **178** | **223** | **249** | **270** | **295** | **322** | **2.1** |
| Brazil | 27 | 41 | 68 | 68 | 68 | 68 | 68 | 1.8 |
| Other | 124 | 137 | 154 | 181 | 201 | 226 | 254 | 2.2 |
| **Total Non-OECD** | **2,110** | **2,204** | **2,639** | **3,287** | **3,997** | **4,827** | **5,604** | **3.4** |
| **Total World** | **4,626** | **4,828** | **5,257** | **6,295** | **7,475** | **8,784** | **10,141** | **2.7** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table H15. World net coal-fired electricity generation by region and country, 2011–40**
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **1,857** | **1,630** | **1,808** | **1,820** | **1,786** | **1,778** | **1,769** | **0.3** |
| United States[a] | 1,733 | 1,514 | 1,709 | 1,724 | 1,713 | 1,704 | 1,702 | 0.4 |
| Canada | 73 | 60 | 43 | 42 | 20 | 21 | 14 | -5.1 |
| Mexico and Chile | 51 | 56 | 55 | 53 | 53 | 53 | 54 | -0.1 |
| OECD Europe | **871** | **930** | **923** | **942** | **915** | **889** | **872** | **-0.2** |
| OECD Asia | **641** | **674** | **662** | **642** | **627** | **624** | **630** | **-0.2** |
| Japan | 265 | 285 | 270 | 260 | 251 | 242 | 233 | -0.7 |
| South Korea | 211 | 225 | 235 | 228 | 227 | 236 | 251 | 0.4 |
| Australia and New Zealand | 165 | 164 | 157 | 154 | 150 | 146 | 146 | -0.4 |
| Total OECD | **3,369** | **3,234** | **3,392** | **3,404** | **3,329** | **3,290** | **3,272** | **0.0** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **391** | **389** | **362** | **352** | **380** | **404** | **414** | **0.2** |
| Russia | 154 | 159 | 152 | 141 | 170 | 196 | 203 | 0.9 |
| Other | 237 | 230 | 209 | 211 | 209 | 209 | 211 | -0.3 |
| Non-OECD Asia | **4,609** | **4,718** | **5,658** | **5,981** | **6,068** | **6,259** | **6,547** | **1.2** |
| China | 3,576 | 3,587 | 4,212 | 4,392 | 4,353 | 4,273 | 4,194 | 0.6 |
| India | 674 | 753 | 944 | 1,016 | 1,087 | 1,281 | 1,536 | 2.6 |
| Other | 359 | 377 | 502 | 574 | 629 | 704 | 817 | 2.8 |
| Middle East | **0** | **0** | **1** | **3** | **4** | **5** | **7** | **—** |
| Africa | **242** | **239** | **283** | **303** | **308** | **322** | **346** | **1.3** |
| Non-OECD Americas | **23** | **24** | **31** | **31** | **31** | **32** | **34** | **1.3** |
| Brazil | 13 | 12 | 18 | 18 | 17 | 17 | 16 | 1.0 |
| Other | 9 | 11 | 13 | 14 | 14 | 16 | 18 | 1.7 |
| Total Non-OECD | **5,266** | **5,369** | **6,335** | **6,670** | **6,792** | **7,023** | **7,349** | **1.1** |
| Total World | **8,635** | **8,604** | **9,727** | **10,074** | **10,121** | **10,313** | **10,621** | **0.8** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H16. World net nuclear electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **888** | **867** | **902** | **891** | **901** | **900** | **924** | **0.2** |
| United States[a] | 790 | 769 | 804 | 808 | 808 | 812 | 833 | 0.3 |
| Canada | 88 | 89 | 86 | 72 | 72 | 67 | 62 | -1.3 |
| Mexico and Chile | 9 | 8 | 12 | 12 | 20 | 20 | 29 | 4.5 |
| OECD Europe | **861** | **837** | **845** | **879** | **930** | **948** | **896** | **0.2** |
| OECD Asia | **304** | **161** | **381** | **437** | **457** | **450** | **427** | **3.5** |
| Japan | 156 | 17 | 167 | 180 | 175 | 169 | 146 | 7.9 |
| South Korea | 148 | 144 | 214 | 258 | 281 | 281 | 281 | 2.4 |
| Australia and New Zealand | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Total OECD | **2,053** | **1,865** | **2,127** | **2,208** | **2,287** | **2,298** | **2,246** | **0.7** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **275** | **279** | **376** | **415** | **411** | **412** | **413** | **1.4** |
| Russia | 162 | 166 | 234 | 267 | 239 | 228 | 223 | 1.0 |
| Other | 113 | 112 | 141 | 148 | 171 | 183 | 190 | 1.9 |
| Non-OECD Asia | **156** | **166** | **459** | **662** | **1,051** | **1,297** | **1,559** | **8.3** |
| China | 83 | 93 | 329 | 452 | 754 | 983 | 1,212 | 9.6 |
| India | 29 | 30 | 67 | 117 | 206 | 222 | 248 | 7.9 |
| Other | 44 | 44 | 63 | 93 | 92 | 92 | 98 | 2.9 |
| Middle East | **0** | **1** | **40** | **63** | **95** | **128** | **152** | **18.4** |
| Africa | **13** | **12** | **14** | **21** | **28** | **35** | **42** | **4.5** |
| Non-OECD Americas | **21** | **21** | **35** | **35** | **74** | **81** | **89** | **5.3** |
| Brazil | 15 | 15 | 23 | 23 | 54 | 54 | 54 | 4.7 |
| Other | 6 | 6 | 12 | 12 | 20 | 27 | 34 | 6.5 |
| Total Non-OECD | **465** | **480** | **924** | **1,196** | **1,659** | **1,953** | **2,255** | **5.7** |
| Total World | **2,518** | **2,345** | **3,051** | **3,404** | **3,946** | **4,251** | **4,501** | **2.4** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table H17. World net hydroelectric and other renewable electricity generation by region and country, 2011–40**
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **1,004** | **987** | **1,278** | **1,376** | **1,472** | **1,598** | **1,763** | **2.1** |
| United States[a] | 535 | 520 | 704 | 741 | 781 | 848 | 934 | 2.1 |
| Canada | 398 | 397 | 459 | 491 | 524 | 557 | 606 | 1.5 |
| Mexico and Chile | 71 | 69 | 115 | 144 | 167 | 193 | 223 | 4.3 |
| **OECD Europe** | **892** | **996** | **1,363** | **1,455** | **1,513** | **1,635** | **1,741** | **2.0** |
| **OECD Asia** | **186** | **185** | **335** | **378** | **427** | **454** | **483** | **3.5** |
| Japan | 118 | 122 | 185 | 205 | 226 | 231 | 231 | 2.3 |
| South Korea | 8 | 7 | 52 | 67 | 83 | 90 | 97 | 9.8 |
| Australia and New Zealand | 60 | 55 | 98 | 106 | 117 | 133 | 155 | 3.7 |
| **Total OECD** | **2,081** | **2,168** | **2,976** | **3,210** | **3,412** | **3,687** | **3,987** | **2.2** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **289** | **291** | **334** | **373** | **393** | **419** | **433** | **1.4** |
| Russia | 168 | 168 | 181 | 217 | 235 | 247 | 247 | 1.4 |
| Other | 121 | 123 | 152 | 155 | 158 | 173 | 186 | 1.5 |
| **Non-OECD Asia** | **1,166** | **1,375** | **2,533** | **3,018** | **3,455** | **3,880** | **4,327** | **4.2** |
| China | 801 | 1,004 | 1,892 | 2,139 | 2,385 | 2,632 | 2,878 | 3.8 |
| India | 173 | 160 | 292 | 439 | 543 | 645 | 764 | 5.7 |
| Other | 192 | 212 | 349 | 440 | 527 | 604 | 685 | 4.3 |
| **Middle East** | **20** | **22** | **72** | **135** | **153** | **222** | **252** | **9.1** |
| **Africa** | **117** | **120** | **157** | **242** | **281** | **323** | **377** | **4.2** |
| **Non-OECD Americas** | **758** | **751** | **803** | **916** | **987** | **1,112** | **1,251** | **1.8** |
| Brazil | 459 | 451 | 488 | 568 | 614 | 708 | 812 | 2.1 |
| Other | 299 | 299 | 314 | 348 | 373 | 404 | 439 | 1.4 |
| **Total Non-OECD** | **2,350** | **2,559** | **3,898** | **4,683** | **5,270** | **5,957** | **6,641** | **3.5** |
| **Total World** | **4,431** | **4,727** | **6,874** | **7,893** | **8,682** | **9,644** | **10,628** | **2.9** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H18. World net hydroelectric electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **747** | **703** | **764** | **784** | **806** | **831** | **887** | **0.8** |
| United States[a] | 319 | 275 | 292 | 294 | 295 | 295 | 297 | 0.3 |
| Canada | 372 | 377 | 403 | 414 | 425 | 437 | 475 | 0.8 |
| Mexico and Chile | 57 | 51 | 68 | 76 | 86 | 99 | 114 | 2.9 |
| OECD Europe | **498** | **556** | **592** | **617** | **617** | **617** | **657** | **0.6** |
| OECD Asia | **128** | **115** | **127** | **131** | **135** | **143** | **153** | **1.0** |
| Japan | 82 | 75 | 83 | 83 | 83 | 85 | 85 | 0.5 |
| South Korea | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 0.7 |
| Australia and New Zealand | 41 | 37 | 39 | 43 | 47 | 54 | 63 | 1.9 |
| Total OECD | **1,374** | **1,375** | **1,482** | **1,532** | **1,558** | **1,592** | **1,696** | **0.8** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **281** | **280** | **310** | **326** | **341** | **364** | **376** | **1.1** |
| Russia | 164 | 164 | 177 | 190 | 204 | 213 | 214 | 0.9 |
| Other | 117 | 116 | 134 | 136 | 138 | 150 | 162 | 1.2 |
| Non-OECD Asia | **994** | **1,160** | **1,620** | **1,747** | **1,825** | **1,959** | **2,105** | **2.2** |
| China | 691 | 856 | 1,162 | 1,198 | 1,234 | 1,270 | 1,306 | 1.5 |
| India | 142 | 125 | 196 | 255 | 287 | 341 | 405 | 4.3 |
| Other | 161 | 179 | 261 | 294 | 303 | 348 | 394 | 2.9 |
| Middle East | **20** | **22** | **38** | **39** | **39** | **42** | **47** | **2.8** |
| Africa | **110** | **113** | **129** | **177** | **185** | **213** | **248** | **2.8** |
| Non-OECD Americas | **709** | **695** | **715** | **806** | **868** | **977** | **1,098** | **1.6** |
| Brazil | 424 | 411 | 428 | 491 | 531 | 611 | 701 | 1.9 |
| Other | 285 | 284 | 287 | 315 | 338 | 366 | 397 | 1.2 |
| Total Non-OECD | **2,114** | **2,270** | **2,812** | **3,095** | **3,258** | **3,554** | **3,875** | **1.9** |
| Total World | **3,488** | **3,645** | **4,294** | **4,626** | **4,816** | **5,146** | **5,571** | **1.5** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H19. World net wind-powered electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **142** | **156** | **295** | **327** | **354** | **404** | **460** | **3.9** |
| United States[a] | 120 | 141 | 232 | 235 | 245 | 278 | 319 | 3.0 |
| Canada | 20 | 11 | 39 | 46 | 53 | 60 | 66 | 6.5 |
| Mexico and Chile | 2 | 4 | 25 | 47 | 57 | 65 | 75 | 11.0 |
| **OECD Europe** | **180** | **208** | **445** | **499** | **556** | **678** | **722** | **4.5** |
| **OECD Asia** | **13** | **14** | **66** | **83** | **106** | **116** | **127** | **8.2** |
| Japan | 4 | 5 | 6 | 13 | 20 | 21 | 21 | 5.4 |
| South Korea | 1 | 1 | 27 | 35 | 47 | 51 | 55 | 15.8 |
| Australia and New Zealand | 8 | 8 | 33 | 35 | 38 | 44 | 51 | 6.7 |
| **Total OECD** | **334** | **379** | **806** | **910** | **1,017** | **1,198** | **1,310** | **4.5** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **3** | **5** | **8** | **18** | **20** | **21** | **22** | **5.2** |
| Russia | 0 | 0 | 0 | 10 | 12 | 13 | 13 | 32.3 |
| Other | 3 | 5 | 8 | 8 | 8 | 9 | 9 | 2.0 |
| **Non-OECD Asia** | **101** | **126** | **462** | **605** | **742** | **870** | **1,002** | **7.7** |
| China | 73 | 96 | 391 | 491 | 592 | 692 | 793 | 7.8 |
| India | 26 | 28 | 59 | 100 | 130 | 155 | 183 | 6.9 |
| Other | 2 | 2 | 13 | 14 | 20 | 23 | 26 | 9.2 |
| **Middle East** | **0** | **0** | **5** | **18** | **24** | **36** | **41** | **—** |
| **Africa** | **3** | **2** | **13** | **28** | **33** | **38** | **44** | **11.0** |
| **Non-OECD Americas** | **5** | **7** | **17** | **24** | **26** | **30** | **34** | **5.7** |
| Brazil | 3 | 5 | 10 | 16 | 18 | 20 | 23 | 5.6 |
| Other | 2 | 2 | 6 | 8 | 9 | 9 | 10 | 5.7 |
| **Total Non-OECD** | **112** | **142** | **506** | **693** | **845** | **995** | **1,143** | **7.7** |
| **Total World** | **447** | **520** | **1,312** | **1,603** | **1,863** | **2,192** | **2,452** | **5.7** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H20. World net geothermal electricity generation by region and country, 2011–40
(billion kilowatthours)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region/country | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **22** | **21** | **37** | **49** | **64** | **75** | **85** | **5.0** |
| United States[a] | 15 | 16 | 27 | 39 | 52 | 62 | 70 | 5.5 |
| Canada | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Mexico and Chile | 7 | 6 | 10 | 10 | 11 | 13 | 15 | 3.5 |
| **OECD Europe** | **11** | **12** | **21** | **23** | **23** | **23** | **25** | **2.7** |
| **OECD Asia** | **9** | **9** | **17** | **18** | **20** | **22** | **25** | **3.9** |
| Japan | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0.1 |
| South Korea | 0 | 0 | 1 | 1 | 2 | 2 | 2 | — |
| Australia and New Zealand | 6 | 6 | 13 | 14 | 16 | 18 | 20 | 4.4 |
| **Total OECD** | **42** | **42** | **74** | **90** | **107** | **121** | **135** | **4.2** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **1** | **0** | **1** | **11** | **13** | **13** | **13** | **12.6** |
| Russia | 1 | 0 | 1 | 11 | 13 | 13 | 13 | 12.6 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| **Non-OECD Asia** | **20** | **20** | **43** | **69** | **134** | **153** | **174** | **8.0** |
| China | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 5.2 |
| India | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Other | 20 | 20 | 42 | 69 | 133 | 152 | 173 | 8.0 |
| **Middle East** | **0** | **0** | **9** | **12** | **18** | **21** | **24** | **—** |
| **Africa** | **2** | **2** | **7** | **21** | **33** | **37** | **43** | **12.5** |
| **Non-OECD Americas** | **3** | **4** | **4** | **5** | **5** | **6** | **6** | **1.6** |
| Brazil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| Other | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 1.6 |
| **Total Non-OECD** | **25** | **26** | **65** | **118** | **202** | **230** | **261** | **8.6** |
| **Total World** | **67** | **68** | **139** | **208** | **309** | **352** | **395** | **6.5** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H21. World net solar electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| **OECD Americas** | **6** | **12** | **57** | **65** | **79** | **96** | **120** | **8.7** |
| United States[a] | 6 | 11 | 51 | 59 | 71 | 88 | 110 | 8.5 |
| Canada | 0 | 0 | 3 | 3 | 4 | 5 | 5 | 10.3 |
| Mexico and Chile | 0 | 0 | 3 | 3 | 4 | 4 | 5 | 16.4 |
| **OECD Europe** | **48** | **71** | **105** | **106** | **106** | **106** | **113** | **1.7** |
| **OECD Asia** | **7** | **10** | **66** | **76** | **85** | **89** | **91** | **8.4** |
| Japan | 5 | 7 | 55 | 62 | 69 | 71 | 71 | 8.6 |
| South Korea | 1 | 1 | 4 | 6 | 6 | 7 | 7 | 7.0 |
| Australia and New Zealand | 1 | 1 | 8 | 8 | 9 | 11 | 12 | 7.8 |
| **Total OECD** | **61** | **92** | **228** | **247** | **270** | **291** | **324** | **4.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **0** | **1** | **4** | **7** | **7** | **8** | **8** | **7.1** |
| Russia | 0 | 0 | 0 | 3 | 3 | 4 | 4 | -- |
| Other | 0 | 1 | 4 | 4 | 4 | 4 | 5 | 5.0 |
| **Non-OECD Asia** | **4** | **9** | **195** | **278** | **355** | **416** | **480** | **15.2** |
| China | 3 | 6 | 175 | 218 | 262 | 306 | 350 | 15.4 |
| India | 1 | 2 | 17 | 53 | 85 | 101 | 120 | 15.6 |
| Other | 0 | 1 | 4 | 7 | 8 | 9 | 10 | 10.2 |
| **Middle East** | **0** | **0** | **12** | **50** | **56** | **95** | **107** | **35.9** |
| **Africa** | **0** | **0** | **4** | **10** | **25** | **29** | **34** | **18.0** |
| **Non-OECD Americas** | **0** | **0** | **5** | **7** | **7** | **8** | **9** | **--** |
| Brazil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- |
| Other | 0 | 0 | 5 | 7 | 7 | 8 | 9 | -- |
| **Total Non-OECD** | **4** | **11** | **219** | **352** | **452** | **556** | **638** | **15.7** |
| **Total World** | **65** | **103** | **448** | **599** | **722** | **847** | **962** | **8.3** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table H22. World net other renewable electricity generation by region and country, 2011–40
(billion kilowatthours)

| Region/country | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012-40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **87** | **94** | **125** | **151** | **169** | **191** | **210** | **2.9** |
| United States[a] | 75 | 77 | 103 | 115 | 119 | 125 | 138 | 2.1 |
| Canada | 6 | 9 | 14 | 28 | 41 | 55 | 60 | 7.0 |
| Mexico and Chile | 6 | 8 | 8 | 8 | 9 | 11 | 13 | 1.8 |
| OECD Europe | **155** | **149** | **201** | **210** | **210** | **210** | **224** | **1.5** |
| OECD Asia | **28** | **37** | **60** | **71** | **80** | **84** | **87** | **3.1** |
| Japan | 23 | 33 | 38 | 44 | 50 | 51 | 51 | 1.5 |
| South Korea | 1 | 1 | 17 | 21 | 24 | 26 | 28 | 12.0 |
| Australia and New Zealand | 4 | 3 | 6 | 6 | 7 | 7 | 9 | 3.9 |
| Total OECD | **270** | **281** | **385** | **432** | **460** | **485** | **522** | **2.2** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **3** | **4** | **10** | **11** | **12** | **13** | **14** | **4.4** |
| Russia | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 0.8 |
| Other | 1 | 1 | 7 | 8 | 9 | 10 | 10 | 8.0 |
| Non-OECD Asia | **47** | **59** | **212** | **319** | **399** | **482** | **566** | **8.4** |
| China | 34 | 45 | 164 | 230 | 296 | 363 | 429 | 8.4 |
| India | 4 | 5 | 20 | 31 | 40 | 47 | 56 | 9.0 |
| Other | 9 | 10 | 29 | 58 | 63 | 72 | 82 | 7.9 |
| Middle East | **0** | **0** | **9** | **16** | **16** | **28** | **32** | **—** |
| Africa | **2** | **2** | **4** | **5** | **5** | **7** | **8** | **4.5** |
| Non-OECD Americas | **41** | **44** | **61** | **74** | **80** | **92** | **105** | **3.1** |
| Brazil | 32 | 35 | 50 | 61 | 66 | 76 | 88 | 3.3 |
| Other | 9 | 9 | 12 | 14 | 15 | 16 | 17 | 2.4 |
| Total Non-OECD | **94** | **110** | **296** | **425** | **513** | **622** | **725** | **7.0** |
| Total World | **364** | **391** | **681** | **857** | **973** | **1,107** | **1,247** | **4.2** |

[a]Includes the 50 states and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: **History:** Derived from U.S. Energy Information Administration (EIA), International Energy Statistics database (as of May 2015), www.eia.gov/ies. **Projections:** EIA, *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

Appendix I

# Reference case projections for natural gas production

**Table I1. World total natural gas production by region, Reference case, 2012–40**
(trillion cubic feet)

| Region/country | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| OECD | | | | | | | |
| **OECD Americas** | **31.8** | **35.7** | **38.6** | **42.1** | **44.6** | **47.3** | **1.4** |
| United States[a] | 24.0 | 28.7 | 30.4 | 32.9 | 34.0 | 35.3 | 1.4 |
| Canada | 6.1 | 5.8 | 6.6 | 7.2 | 7.9 | 8.6 | 1.2 |
| Mexico | 1.7 | 1.2 | 1.5 | 2.0 | 2.6 | 3.3 | 2.5 |
| Chile | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 1.5 |
| **OECD Europe** | **10.3** | **8.7** | **9.1** | **10.1** | **11.1** | **11.9** | **0.5** |
| North Europe | 9.9 | 8.1 | 8.3 | 9.2 | 10.0 | 10.5 | 0.2 |
| South Europe | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.8 | 3.7 |
| Southwest Europe | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.9 |
| Turkey and Israel | 0.1 | 0.2 | 0.4 | 0.4 | 0.5 | 0.5 | 6.0 |
| **OECD Asia** | **2.3** | **3.5** | **4.3** | **5.1** | **6.1** | **7.2** | **4.2** |
| Japan | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| South Korea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 |
| Australia and New Zealand | 2.1 | 3.3 | 4.2 | 5.0 | 5.9 | 7.0 | 4.4 |
| **Total OECD** | **44.4** | **47.9** | **52.0** | **57.4** | **61.9** | **66.4** | **1.4** |
| Non-OECD | | | | | | | |
| **Non-OECD Europe and Eurasia** | **28.5** | **28.9** | **30.4** | **33.2** | **37.3** | **40.9** | **1.3** |
| Russia | 21.8 | 21.9 | 23.4 | 25.9 | 29.3 | 31.8 | 1.4 |
| Central Asia | 5.5 | 5.8 | 5.7 | 5.9 | 6.4 | 7.1 | 0.9 |
| Non-OECD Europe | 1.2 | 1.2 | 1.3 | 1.4 | 1.6 | 2.0 | 2.0 |
| **Non-OECD Asia** | **14.6** | **18.3** | **22.5** | **26.4** | **30.1** | **33.3** | **3.0** |
| China | 3.7 | 7.2 | 11.1 | 14.2 | 16.7 | 18.7 | 6.0 |
| India | 1.4 | 1.5 | 1.6 | 1.7 | 1.9 | 2.1 | 1.3 |
| LNG Exporters | 5.2 | 5.5 | 5.9 | 6.4 | 7.0 | 7.5 | 1.4 |
| Other Asia | 4.3 | 4.0 | 3.9 | 4.1 | 4.5 | 5.0 | 0.5 |
| **Middle East** | **19.2** | **23.0** | **26.3** | **29.7** | **32.8** | **35.8** | **2.3** |
| Arabian Producers | 4.3 | 5.5 | 5.6 | 6.0 | 6.5 | 7.0 | 1.7 |
| Iran | 5.6 | 7.4 | 8.7 | 10.1 | 11.4 | 12.4 | 2.9 |
| Iraq | 0.0 | 0.0 | 0.3 | 0.5 | 0.7 | 1.0 | 15.0 |
| Qatar | 5.5 | 5.8 | 7.0 | 7.6 | 8.0 | 8.4 | 1.5 |
| Saudi Arabia | 3.5 | 4.0 | 4.7 | 5.5 | 6.2 | 6.9 | 2.4 |
| Other Middle East | 0.3 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | -1.3 |
| **Africa** | **7.6** | **9.8** | **11.2** | **13.2** | **14.9** | **16.5** | **2.8** |
| North Africa | 5.6 | 7.1 | 7.1 | 7.1 | 7.3 | 7.7 | 1.1 |
| West Africa | 1.7 | 2.3 | 3.6 | 5.5 | 6.8 | 7.9 | 5.6 |
| East Africa | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.6 | 4.6 |
| Other Africa | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 6.8 |
| **Non-OECD Americas** | **5.5** | **6.1** | **7.0** | **7.6** | **8.4** | **9.4** | **2.0** |
| Brazil | 0.6 | 0.9 | 1.0 | 1.1 | 1.4 | 1.8 | 4.0 |
| Northern Producers | 2.5 | 2.9 | 3.3 | 3.3 | 3.3 | 3.5 | 1.1 |
| Southern Cone | 1.3 | 1.3 | 1.9 | 2.3 | 2.8 | 3.1 | 3.3 |
| Andean | 1.1 | 1.0 | 0.9 | 0.8 | 0.9 | 1.0 | -0.4 |
| Central America and Caribbean | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 3.1 |
| **Total Non-OECD** | **75.3** | **86.1** | **97.4** | **110.1** | **123.5** | **136.0** | **2.1** |
| **Total World** | **119.7** | **134.0** | **149.4** | **167.5** | **185.4** | **202.4** | **1.9** |
| Discrepancy[b] | -0.1 | 0.8 | 0.4 | 0.9 | 0.1 | -0.9 | |

[a]Includes supplemental production less any forecast discrepancy.
[b]Balancing item. Differences between global production and consumption totals results from independent rounding and differences in conversion factors derived from heat contents of natural gas that is produced and consumed regionally.
Sources: **History:** EIA, International Energy Statistics database (as of November 2015), www.eia.gov/ies. **Projections:** United States: EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC, April 2015), www.eia.gov/aeo. **Others:** EIA, International Natural Gas Model (2016).

## Table I2. World tight gas, shale gas and coalbed methane production by region, Reference case, 2012–40
(trillion cubic feet)

| Region/country | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| OECD | | | | | | | |
| OECD Americas | **19.8** | **26.0** | **29.0** | **31.4** | **34.3** | **37.0** | **2.3** |
| United States[a] | 16.6 | 22.1 | 23.9 | 25.1 | 26.5 | 27.8 | 1.9 |
| Canada | 3.3 | 3.8 | 4.9 | 5.5 | 6.3 | 7.0 | 2.8 |
| Mexico | 0.0 | 0.1 | 0.3 | 0.8 | 1.4 | 2.2 | — |
| Chile | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| OECD Europe | **0.0** | **0.5** | **1.7** | **3.3** | **4.6** | **5.5** | **21.8** |
| North Europe | 0.0 | 0.5 | 1.6 | 3.0 | 4.1 | 4.9 | 21.3 |
| South Europe | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | — |
| Southwest Europe | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Turkey and Israel | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | — |
| OECD Asia | **0.3** | **1.1** | **1.7** | **2.3** | **3.1** | **4.0** | **9.4** |
| Japan | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| South Korea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Australia and New Zealand | 0.3 | 1.1 | 1.7 | 2.3 | 3.1 | 4.0 | 9.6 |
| Total OECD | **20.2** | **27.6** | **32.5** | **37.0** | **42.0** | **46.5** | **3.0** |
| Non-OECD | | | | | | | |
| Non-OECD Europe and Eurasia | **0.4** | **0.4** | **0.8** | **1.9** | **4.3** | **7.2** | **11.3** |
| Russia | 0.4 | 0.4 | 0.6 | 1.4 | 3.0 | 5.0 | 9.9 |
| Central Asia | 0.0 | 0.0 | 0.1 | 0.4 | 0.9 | 1.5 | — |
| Non-OECD Europe | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.7 | — |
| Non-OECD Asia | **1.7** | **4.6** | **8.5** | **12.0** | **15.2** | **17.9** | **8.8** |
| China | 1.5 | 4.1 | 7.7 | 10.5 | 12.9 | 14.7 | 8.4 |
| India | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | — |
| LNG Exporters | 0.2 | 0.4 | 0.6 | 0.9 | 1.2 | 1.4 | 8.2 |
| Other Asia | 0.0 | 0.0 | 0.1 | 0.4 | 0.8 | 1.2 | — |
| Middle East | **0.0** | **0.0** | **0.0** | **0.2** | **0.6** | **1.1** | **34.8** |
| Arabian Producers | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.5 | 31.1 |
| Iran | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.5 | — |
| Iraq | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Qatar | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Saudi Arabia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Other Middle East | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | — |
| Africa | **0.0** | **0.0** | **0.8** | **1.1** | **2.8** | **4.2** | **27.8** |
| North Africa | 0.0 | 0.1 | 0.5 | 1.2 | 1.8 | 2.4 | 25.2 |
| West Africa | 0.0 | -0.2 | 0.0 | -0.3 | 0.6 | 1.4 | — |
| East Africa | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Other Africa | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | — |
| Non-OECD Americas | **0.0** | **0.4** | **1.1** | **1.9** | **3.0** | **4.0** | **17.3** |
| Brazil | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.4 | — |
| Northern Producers | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 | 0.8 | — |
| Southern Cone | 0.0 | 0.4 | 1.1 | 1.6 | 2.1 | 2.6 | 15.5 |
| Andean | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | — |
| Central America and Caribbean | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total Non-OECD | **2.1** | **5.5** | **11.2** | **17.2** | **25.8** | **34.3** | **10.5** |
| Total World | **22.3** | **33.1** | **43.8** | **54.2** | **67.8** | **80.9** | **4.7** |

[a]Includes supplemental production less any forecast discrepancy.
Sources: **History:** EIA, International Energy Statistics database (as of November 2015), www.eia.gov/ies. **Projections:** United States: EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC, April 2015), www.eia.gov/aeo. **Others:** EIA, International Natural Gas Model (2016).

**Table I3. World other natural gas production by region, Reference case, 2012–40**
(trillion cubic feet)

| Region/country | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| OECD | | | | | | | |
| **OECD Americas** | **12.0** | **9.8** | **9.5** | **10.7** | **10.3** | **10.3** | **-0.5** |
| United States[a] | 7.5 | 6.6 | 6.5 | 7.8 | 7.5 | 7.5 | 0.0 |
| Canada | 2.8 | 2.0 | 1.8 | 1.7 | 1.6 | 1.5 | -2.2 |
| Mexico | 1.7 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | -1.2 |
| Chile | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 2.6 |
| **OECD Europe** | **10.2** | **8.2** | **7.4** | **6.9** | **6.5** | **6.3** | **-1.7** |
| North Europe | 9.9 | 7.6 | 6.7 | 6.2 | 5.8 | 5.6 | -2.0 |
| South Europe | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 1.3 |
| Southwest Europe | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Turkey and Israel | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | — |
| **OECD Asia** | **2.0** | **2.3** | **2.6** | **2.8** | **3.0** | **3.2** | **1.7** |
| Japan | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | -1.4 |
| South Korea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Australia and New Zealand | 1.8 | 2.2 | 2.4 | 2.6 | 2.9 | 3.1 | 1.9 |
| Total OECD | **24.2** | **20.3** | **19.5** | **20.3** | **19.9** | **19.9** | |
| Non-OECD | | | | | | | |
| **Non-OECD Europe and Eurasia** | **28.1** | **28.5** | **29.6** | **31.3** | **33.1** | **33.7** | **0.6** |
| Russia | 21.4 | 21.6 | 22.8 | 24.5 | 26.3 | 26.8 | 0.8 |
| Central Asia | 5.5 | 5.8 | 5.6 | 5.5 | 5.5 | 5.6 | 0.1 |
| Non-OECD Europe | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 0.3 |
| **Non-OECD Asia** | **12.9** | **13.6** | **14.0** | **14.3** | **14.8** | **15.4** | **0.6** |
| China | 2.1 | 3.1 | 3.5 | 3.6 | 3.8 | 3.9 | 2.2 |
| India | 1.4 | 1.4 | 1.4 | 1.4 | 1.5 | 1.6 | 0.4 |
| LNG Exporters | 5.0 | 5.1 | 5.3 | 5.6 | 5.8 | 6.1 | 0.7 |
| Other Asia | 4.3 | 4.0 | 3.8 | 3.7 | 3.7 | 3.8 | -0.4 |
| **Middle East** | **19.2** | **23.0** | **26.3** | **29.5** | **32.2** | **34.7** | **2.1** |
| Arabian Producers | 4.3 | 5.5 | 5.5 | 5.9 | 6.2 | 6.5 | 1.5 |
| Iran | 5.6 | 7.4 | 8.7 | 10.0 | 11.1 | 11.9 | 2.7 |
| Iraq | 0.0 | 0.0 | 0.3 | 0.5 | 0.7 | 1.0 | 15.0 |
| Qatar | 5.5 | 5.8 | 7.0 | 7.6 | 8.0 | 8.4 | — |
| Saudi Arabia | 3.5 | 4.0 | 4.7 | 5.5 | 6.2 | 6.9 | 2.4 |
| Other Middle East | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | -3.3 |
| **Africa** | **7.5** | **9.8** | **10.5** | **12.1** | **12.1** | **12.3** | **1.8** |
| North Africa | 5.6 | 6.9 | 6.5 | 5.9 | 5.4 | 5.3 | -0.2 |
| West Africa | 1.7 | 2.5 | 3.6 | 5.8 | 6.2 | 6.5 | 4.9 |
| East Africa | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.6 | 4.7 |
| Other Africa | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| **Non-OECD Americas** | **5.4** | **5.6** | **5.9** | **5.7** | **5.4** | **5.4** | **—** |
| Brazil | 0.6 | 0.8 | 0.9 | 1.0 | 1.1 | 1.4 | 3.1 |
| Northern Producers | 2.5 | 2.9 | 3.3 | 3.2 | 2.9 | 2.7 | 0.2 |
| Southern Cone | 1.2 | 0.9 | 0.8 | 0.7 | 0.7 | 0.6 | -2.5 |
| Andean | 1.1 | 1.0 | 0.8 | 0.8 | 0.8 | 0.7 | -1.5 |
| Central America and Caribbean | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Total Non-OECD | **73.2** | **80.6** | **86.2** | **92.9** | **97.7** | **101.6** | **1.2** |
| Total World | **97.4** | **100.9** | **105.7** | **113.3** | **117.6** | **121.5** | **—** |

[a]Includes supplemental production less any forecast discrepancy.
Sources: **History:** EIA, International Energy Statistics database (as of November 2015), www.eia.gov/ies. **Projections:** United States: EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC, April 2015), www.eia.gov/aeo. **Others:** EIA, International Natural Gas Model (2016).

## Table I4. World net trade in natural gas by region, Reference case, 2012–40
(trillion cubic feet)

| Region/country | 2012 | Projections 2020 | 2025 | 2030 | 2035 | 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|
| OECD | | | | | | | |
| **OECD Americas** | **0.3** | **-2.6** | **-4.0** | **-5.4** | **-6.2** | **-6.9** | **—** |
| United States[a] | 1.5 | -2.6 | -3.5 | -4.8 | -5.2 | -5.6 | — |
| Canada | -2.3 | -1.9 | -2.3 | -2.4 | -2.7 | -2.8 | 0.7 |
| Mexico | 1.0 | 1.7 | 1.7 | 1.6 | 1.5 | 1.3 | 1.1 |
| Chile | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 1.7 |
| **OECD Europe** | **7.8** | **10.9** | **11.9** | **12.7** | **13.0** | **14.0** | **2.1** |
| North Europe | 2.4 | 5.2 | 5.9 | 6.1 | 6.1 | 6.3 | 3.5 |
| South Europe | 2.5 | 2.6 | 2.8 | 3.1 | 3.3 | 3.6 | 1.3 |
| Southwest Europe | 1.4 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.0 |
| Turkey and Israel | 1.6 | 1.7 | 1.7 | 1.9 | 2.0 | 2.3 | 1.4 |
| **OECD Asia** | **5.3** | **5.4** | **5.4** | **5.2** | **5.2** | **5.0** | **-0.2** |
| Japan | 4.3 | 5.0 | 5.4 | 5.5 | 5.7 | 5.8 | 1.1 |
| South Korea | 1.7 | 2.1 | 2.2 | 2.4 | 2.7 | 3.0 | 2.1 |
| Australia and New Zealand | -0.7 | -1.7 | -2.2 | -2.7 | -3.2 | -3.8 | 6.3 |
| **Total OECD** | **13.4** | **13.7** | **13.3** | **12.5** | **12.1** | **12.0** | **-0.4** |
| Non-OECD | | | | | | | |
| **Non-OECD Europe and Eurasia** | **-5.4** | **-6.5** | **-6.6** | **-8.3** | **-10.9** | **-15.0** | **3.7** |
| Russia | -6.1 | -6.6 | -7.6 | -9.7 | -12.3 | -15.6 | 3.4 |
| Central Asia | -1.9 | -2.2 | -1.6 | -1.4 | -1.6 | -2.0 | 0.3 |
| Non-OECD Europe | 2.5 | 2.3 | 2.6 | 2.8 | 2.9 | 2.6 | 0.2 |
| **Non-OECD Asia** | **0.5** | **2.7** | **4.7** | **7.7** | **12.4** | **17.5** | **13.4** |
| China | 1.4 | 2.1 | 2.4 | 3.4 | 6.0 | 8.9 | 6.8 |
| India | 0.6 | 0.8 | 1.3 | 2.1 | 3.0 | 3.9 | 6.7 |
| LNG Exporters | -2.7 | -2.6 | -2.6 | -2.6 | -2.7 | -2.7 | 0.0 |
| Other Asia | 1.2 | 2.5 | 3.6 | 4.9 | 6.1 | 7.4 | 6.8 |
| **Middle East** | **-4.4** | **-5.2** | **-5.9** | **-6.2** | **-6.8** | **-7.2** | **1.7** |
| Arabian Producers | -0.2 | -0.7 | 0.2 | 0.7 | 0.9 | 1.2 | — |
| Iran | -0.1 | -0.8 | -1.2 | -1.4 | -1.9 | -2.0 | 11.9 |
| Iraq | 0.0 | 0.0 | -0.3 | -0.5 | -0.7 | -1.1 | — |
| Qatar | -4.1 | -3.9 | -4.8 | -5.3 | -5.5 | -5.8 | 1.2 |
| Saudi Arabia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — |
| Other Middle East | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | — |
| **Africa** | **-3.4** | **-4.4** | **-5.0** | **-5.5** | **-5.5** | **-5.4** | **1.7** |
| North Africa | -2.3 | -3.3 | -2.5 | -1.1 | 0.1 | 1.2 | — |
| West Africa | -1.1 | -1.1 | -2.5 | -4.4 | -5.5 | -6.4 | 6.5 |
| East Africa | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.2 | 2.4 |
| Other Africa | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | — |
| **Non-OECD Americas** | **-0.6** | **-0.3** | **-0.5** | **-0.4** | **-0.5** | **-0.7** | **0.4** |
| Brazil | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.4 | -0.6 |
| Northern Producers | -0.7 | -0.9 | -1.1 | -1.0 | -0.8 | -0.8 | 0.5 |
| Southern Cone | 0.1 | 0.4 | 0.1 | -0.1 | -0.3 | -0.4 | — |
| Andean | -0.6 | -0.4 | -0.2 | 0.0 | 0.0 | 0.0 | — |
| Central America and Caribbean | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.9 |
| **Total Non-OECD** | **-13.4** | **-13.6** | **-13.3** | **-12.7** | **-11.3** | **-10.8** | **-0.8** |
| **Total World** | **0.0** | **0.1** | **0.1** | **-0.2** | **0.8** | **1.2** | **13.3** |

[a]Includes supplemental production less any forecast discrepancy.
Sources: **History:** EIA, International Energy Statistics database (as of November 2015), www.eia.gov/ies. **Projections:** United States: EIA, *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC, April 2015), www.eia.gov/aeo. **Others:** EIA, International Natural Gas Model (2016).

Appendix J

# Kaya Identity factor projections

- *Carbon dioxide intensity*
- *Energy intensity*
- *GDP per capita*
- *Population*

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**Table J1. World carbon dioxide intensity of energy use by region, Reference case, 2011–40**
(metric tons per billion Btu)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012-40 |
| OECD | | | | | | | | |
| **OECD Americas** | **53.6** | **53.0** | **52.3** | **51.7** | **51.1** | **50.6** | **49.9** | **-0.2** |
| United States[a] | 55.7 | 55.0 | 54.5 | 54.0 | 53.6 | 53.2 | 52.5 | -0.2 |
| Canada | 38.8 | 38.9 | 37.0 | 37.0 | 36.1 | 36.2 | 35.8 | -0.3 |
| Mexico and Chile | 55.1 | 55.3 | 52.4 | 50.7 | 49.5 | 49.0 | 48.2 | -0.5 |
| **OECD Europe** | **51.2** | **50.7** | **48.3** | **47.7** | **47.1** | **46.4** | **46.2** | **-0.3** |
| **OECD Asia** | **57.5** | **59.6** | **54.4** | **53.0** | **52.1** | **51.9** | **51.8** | **-0.5** |
| Japan | 55.9 | 60.1 | 53.7 | 52.6 | 51.9 | 51.6 | 51.8 | -0.5 |
| South Korea | 56.7 | 56.1 | 52.8 | 50.6 | 49.5 | 49.9 | 50.3 | -0.4 |
| Australia and New Zealand | 63.8 | 63.8 | 59.4 | 58.4 | 57.2 | 55.9 | 54.6 | -0.6 |
| **Total OECD** | **53.4** | **53.3** | **51.3** | **50.6** | **49.9** | **49.4** | **49.0** | **-0.3** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **57.0** | **58.0** | **56.2** | **55.5** | **55.5** | **55.3** | **55.0** | **-0.2** |
| Russia | 54.9 | 56.0 | 54.7 | 53.7 | 54.0 | 54.2 | 54.0 | -0.1 |
| Other | 60.4 | 61.3 | 58.9 | 58.6 | 57.8 | 57.0 | 56.5 | -0.3 |
| **Non-OECD Asia** | **70.1** | **69.3** | **64.9** | **62.9** | **60.7** | **59.2** | **58.0** | **-0.6** |
| China | 74.2 | 72.8 | 67.0 | 65.1 | 62.4 | 60.2 | 58.1 | -0.8 |
| India | 66.6 | 68.0 | 65.4 | 62.3 | 60.0 | 59.9 | 59.9 | -0.5 |
| Other | 59.3 | 58.7 | 57.5 | 56.4 | 56.0 | 55.9 | 56.0 | -0.2 |
| **Middle East** | **61.2** | **59.8** | **58.8** | **57.4** | **56.9** | **56.0** | **55.7** | **-0.2** |
| **Africa** | **55.7** | **55.0** | **55.0** | **53.2** | **52.1** | **51.4** | **50.9** | **-0.3** |
| **Non-OECD Americas** | **40.7** | **41.0** | **41.7** | **41.1** | **40.5** | **39.9** | **39.4** | **-0.1** |
| Brazil | 32.1 | 32.9 | 33.7 | 33.0 | 32.5 | 31.9 | 31.4 | -0.2 |
| Other | 48.8 | 48.7 | 49.4 | 48.9 | 48.5 | 48.1 | 47.9 | -0.1 |
| **Total Non-OECD** | **63.0** | **62.7** | **60.3** | **58.7** | **57.2** | **56.1** | **55.2** | **-0.5** |
| **Total World** | **58.7** | **58.6** | **56.7** | **55.5** | **54.5** | **53.7** | **53.0** | **-0.4** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table J2. World energy intensity by region, Reference case, 2011–40
(thousand Btu per 2010 dollar of GDP)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **6.5** | **6.2** | **5.4** | **4.8** | **4.4** | **4.0** | **3.7** | **-1.9** |
| United States[a] | 6.4 | 6.1 | 5.4 | 4.8 | 4.3 | 3.9 | 3.5 | -2.0 |
| Canada | 10.4 | 10.2 | 8.9 | 8.3 | 7.8 | 7.5 | 7.1 | -1.3 |
| Mexico and Chile | 4.2 | 4.0 | 3.4 | 3.1 | 2.9 | 2.8 | 2.7 | -1.4 |
| **OECD Europe** | **4.4** | **4.4** | **3.9** | **3.7** | **3.5** | **3.3** | **3.2** | **-1.1** |
| **OECD Asia** | **5.7** | **5.5** | **5.4** | **5.3** | **5.1** | **4.9** | **4.8** | **-0.5** |
| Japan | 4.9 | 4.7 | 4.7 | 4.6 | 4.4 | 4.3 | 4.1 | -0.5 |
| South Korea | 7.4 | 7.3 | 7.1 | 6.9 | 6.6 | 6.4 | 6.1 | -0.6 |
| Australia and New Zealand | 6.4 | 6.1 | 5.5 | 5.2 | 4.9 | 4.6 | 4.5 | -1.1 |
| **Total OECD** | **5.5** | **5.3** | **4.8** | **4.4** | **4.1** | **3.9** | **3.6** | **-1.4** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **9.3** | **9.2** | **7.8** | **7.1** | **6.3** | **5.5** | **4.9** | **-2.2** |
| Russia | 9.7 | 9.8 | 9.1 | 8.4 | 7.6 | 6.9 | 6.1 | -1.7 |
| Other | 8.6 | 8.2 | 6.3 | 5.5 | 4.8 | 4.2 | 3.7 | -2.8 |
| **Non-OECD Asia** | **6.4** | **6.3** | **5.0** | **4.4** | **3.9** | **3.5** | **3.2** | **-2.4** |
| China | 8.2 | 8.0 | 6.4 | 5.4 | 4.7 | 4.1 | 3.7 | -2.8 |
| India | 4.4 | 4.4 | 3.2 | 2.9 | 2.6 | 2.5 | 2.3 | -2.3 |
| Other | 4.6 | 4.5 | 3.9 | 3.7 | 3.4 | 3.2 | 3.0 | -1.5 |
| **Middle East** | **6.0** | **6.2** | **5.9** | **5.3** | **4.9** | **4.7** | **4.4** | **-1.3** |
| **Africa** | **4.6** | **4.7** | **4.0** | **3.6** | **3.2** | **2.9** | **2.6** | **-2.2** |
| **Non-OECD Americas** | **4.7** | **4.7** | **4.2** | **4.0** | **3.8** | **3.6** | **3.5** | **-1.1** |
| Brazil | 5.1 | 5.1 | 4.8 | 4.6 | 4.4 | 4.3 | 4.3 | -0.7 |
| Other | 4.5 | 4.3 | 3.8 | 3.5 | 3.3 | 3.1 | 2.9 | -1.4 |
| **Total Non-OECD** | **6.3** | **6.3** | **5.2** | **4.6** | **4.1** | **3.7** | **3.4** | **-2.2** |
| **Total World** | **5.9** | **5.8** | **5.0** | **4.5** | **4.1** | **3.8** | **3.4** | **-1.9** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **United States:** U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo. **Other countries:** Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site); and EIA, World Energy Projections Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

**Table J3. World gross domestic product (GDP) per capita by region expressed in purchasing power parity, Reference case, 2011–40**
(2010 dollars per person)

| | History | | Projections | | | | | Average annual percent change, |
|---|---|---|---|---|---|---|---|---|
| Region | 2011 | 2012 | 2020 | 2025 | 2030 | 2035 | 2040 | 2012–40 |
| OECD | | | | | | | | |
| **OECD Americas** | **38,441** | **39,055** | **44,716** | **48,842** | **53,114** | **57,747** | **63,278** | **1.7** |
| United States[a] | 48,094 | 48,865 | 56,285 | 61,453 | 66,639 | 72,107 | 78,670 | 1.7 |
| Canada | 40,487 | 40,781 | 45,027 | 47,641 | 50,396 | 53,676 | 57,265 | 1.2 |
| Mexico and Chile | 16,000 | 16,448 | 19,098 | 21,503 | 24,229 | 27,343 | 30,941 | 2.3 |
| **OECD Europe** | **34,070** | **33,869** | **38,062** | **41,353** | **44,611** | **48,001** | **51,742** | **1.5** |
| **OECD Asia** | **33,996** | **34,614** | **38,765** | **41,195** | **43,684** | **46,505** | **49,456** | **1.3** |
| Japan | 33,771 | 34,382 | 37,500 | 39,720 | 41,754 | 43,805 | 45,297 | 1.0 |
| South Korea | 31,272 | 31,813 | 38,529 | 41,320 | 44,559 | 48,357 | 52,905 | 1.8 |
| Australia and New Zealand | 39,986 | 40,699 | 44,228 | 46,433 | 48,930 | 52,325 | 56,869 | 1.2 |
| **Total OECD** | **35,771** | **36,030** | **40,862** | **44,407** | **48,024** | **51,915** | **56,376** | **1.6** |
| Non-OECD | | | | | | | | |
| **Non-OECD Europe and Eurasia** | **15,706** | **16,151** | **19,285** | **22,782** | **26,713** | **31,322** | **36,054** | **2.9** |
| Russia | 22,091 | 22,891 | 26,081 | 30,069 | 34,557 | 39,819 | 44,388 | 2.4 |
| Other | 11,116 | 11,326 | 14,611 | 17,904 | 21,590 | 25,896 | 30,841 | 3.6 |
| **Non-OECD Asia** | **7,115** | **7,484** | **10,998** | **13,519** | **16,254** | **19,363** | **22,959** | **4.1** |
| China | 9,679 | 10,359 | 16,134 | 20,356 | 24,981 | 30,183 | 36,094 | 4.6 |
| India | 4,643 | 4,787 | 7,474 | 9,420 | 11,559 | 14,081 | 17,120 | 4.7 |
| Other | 6,672 | 6,927 | 8,881 | 10,346 | 11,993 | 13,931 | 16,246 | 3.1 |
| **Middle East** | **23,731** | **23,663** | **27,961** | **31,681** | **35,181** | **38,484** | **41,600** | **2.0** |
| **Africa** | **4,168** | **4,261** | **5,094** | **5,804** | **6,672** | **7,717** | **8,949** | **2.7** |
| **Non-OECD Americas** | **13,749** | **13,963** | **15,432** | **17,150** | **18,778** | **20,562** | **22,646** | **1.7** |
| Brazil | 14,743 | 14,874 | 16,103 | 18,109 | 20,133 | 22,364 | 24,948 | 1.9 |
| Other | 13,020 | 13,299 | 14,965 | 16,500 | 17,886 | 19,413 | 21,223 | 1.7 |
| **Total Non-OECD** | **8,236** | **8,522** | **11,273** | **13,372** | **15,592** | **18,057** | **20,812** | **3.2** |
| **Total World** | **13,102** | **13,355** | **16,250** | **18,466** | **20,795** | **23,370** | **26,274** | **2.4** |

[a]Includes the 50 States and the District of Columbia.
Notes: Totals may not equal sum of components due to independent rounding.
Sources: U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2015*, DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo; and World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table J4. World population by region, Reference case, 2011–2040
(millions)

| Region | History 2011 | History 2012 | Projections 2020 | Projections 2025 | Projections 2030 | Projections 2035 | Projections 2040 | Average annual percent change, 2012–40 |
|---|---|---|---|---|---|---|---|---|
| OECD | | | | | | | | |
| OECD Americas | **484** | **489** | **523** | **544** | **564** | **581** | **597** | **0.7** |
| United States[a] | 312 | 315 | 334 | 347 | 359 | 370 | 380 | 0.7 |
| Canada | 34 | 35 | 38 | 39 | 41 | 43 | 44 | 0.8 |
| Mexico and Chile | 137 | 139 | 151 | 158 | 164 | 169 | 173 | 0.8 |
| OECD Europe | **548** | **550** | **565** | **571** | **576** | **579** | **581** | **0.2** |
| OECD Asia | **203** | **204** | **207** | **208** | **208** | **207** | **206** | **0.0** |
| Japan | 127 | 127 | 125 | 123 | 120 | 117 | 114 | -0.4 |
| South Korea | 49 | 49 | 51 | 52 | 52 | 52 | 52 | 0.2 |
| Australia and New Zealand | 27 | 27 | 31 | 33 | 36 | 38 | 40 | 1.3 |
| Total OECD | **1,235** | **1,243** | **1,295** | **1,323** | **1,348** | **1,368** | **1,384** | **0.4** |
| Non-OECD | | | | | | | | |
| Non-OECD Europe and Eurasia | **343** | **343** | **343** | **341** | **337** | **333** | **329** | **-0.1** |
| Russia | 143 | 143 | 140 | 137 | 133 | 130 | 127 | -0.4 |
| Other | 199 | 200 | 203 | 204 | 204 | 203 | 203 | 0.1 |
| Non-OECD Asia | **3,691** | **3,730** | **4,013** | **4,159** | **4,278** | **4,373** | **4,443** | **0.6** |
| China | 1,373 | 1,381 | 1,435 | 1,450 | 1,453 | 1,448 | 1,434 | 0.1 |
| India | 1,229 | 1,244 | 1,360 | 1,425 | 1,482 | 1,530 | 1,569 | 0.8 |
| Other | 1,089 | 1,104 | 1,218 | 1,284 | 1,343 | 1,396 | 1,441 | 1.0 |
| Middle East | **210** | **214** | **249** | **271** | **293** | **316** | **340** | **1.7** |
| Africa | **1,045** | **1,070** | **1,284** | **1,429** | **1,583** | **1,745** | **1,916** | **2.1** |
| Non-OECD Americas | **467** | **473** | **515** | **540** | **562** | **583** | **601** | **0.9** |
| Brazil | 198 | 200 | 212 | 218 | 223 | 227 | 230 | 0.5 |
| Other | 270 | 273 | 304 | 322 | 339 | 356 | 372 | 1.1 |
| Total Non-OECD | **5,756** | **5,830** | **6,404** | **6,739** | **7,054** | **7,351** | **7,630** | **1.0** |
| Total World | **6,991** | **7,073** | **7,699** | **8,063** | **8,402** | **8,719** | **9,014** | **0.9** |

[a]Includes the 50 States and the District of Columbia.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **United States:** U.S. Energy Information Administration (EIA), *Annual Energy Outlook 2015,* DOE/EIA-0383(2015) (Washington, DC: April 2015); AEO2015 National Energy Modeling System, run REF2015.D021915A, www.eia.gov/aeo. **Other countries:** Oxford Economic Model (June 2015), www.oxfordeconomics.com (subscription site).

## Appendix K

# Comparisons with International Energy Agency and IEO2013 projections

## Comparisons with IEA's *World Energy Outlook 2015*

The International Energy Agency (IEA) in its *World Energy Outlook 2015* (WEO2015) provides projections comparable with those in IEO2016. Both outlooks extend to 2040. In IEO2016 the most recent historical data year is 2012; in WEO2015 the most recent historical data year is 2013. Accordingly, comparisons are made between two time periods, 2012/2013–20 and 2020–40.

The IEA WEO2015 includes four cases (scenarios): (1) New Policies Scenario (the report's "central scenario"), (2) Current Policies Scenario, (3) 450 Scenario, and (4) Low Oil Price Scenario. Much of the text of the IEA report concentrates on the New Policies Scenario, which ". . . takes into account the policies and implementing measures affecting energy markets that had been adopted as of mid-2015 (as well as the energy-related components of climate pledges in the run-up to COP21, submitted by 1 October), together with relevant declared policy intentions, even though specific measures needed to put them into effect may not have been adopted."[1] The IEA Current Policies Scenario "takes into account only policies enacted as of mid-2015." Accordingly, the IEA Current Policies Scenario is used here for comparison with the IEO2016 Reference case.

World oil price assumptions show similar trajectories in the IEO2016 Reference case and the IEA Current Policies Scenario. In both cases, oil prices in 2020 are lower than 2014 prices, and after 2020 oil prices rise through 2040. In the IEO2016 Reference case, Brent crude oil prices in 2020 are $79 per barrel ($79/b),[2] or about 19% lower than the 2014 Brent crude oil price of $97/b. In the IEA Current Policies Scenario, the 2020 price of imported crude oil ($82/b) is 14% lower than the 2014 price ($95/b). In the 2020–30 period, crude oil prices in the IEA Current Policies Scenario rise more rapidly than in the IEO2016 Reference case, with IEA prices averaging an increase of 4.6%/year and IEO2016 Reference case prices averaging an increase of 2.9%/year. After 2030, growth in the IEA crude oil import price slows to an average of 1.4%/year through 2040, whereas in the IEO2016 Reference case, Brent crude oil prices continue to increase by an average of 2.9%/year from 2030 to 2040. In 2040, the Brent crude oil price is $141/b in the IEO2016 Reference case, and the IEA crude import price is $148/b in the IEA Current Policies Scenario. Despite the differences in mid-term price assumptions, world demand for liquid fuels is similar in the two outlooks: 99.5 million barrels per day (b/d) in 2020 in the IEA Current Policies Scenario and 99.6 million b/d[3] in the IEO2016 Reference case, and 120.7 million b/d in 2040 in the IEA Current Policies Scenario and 119.7 million b/d in the IEO2016 Reference case.

### Table K1. Comparison of IEO2016 and IEA world energy consumption growth rates by region, 2012–20 (average annual percent growth)

| Region | IEO2016 Reference Case | IEA Current Policies Scenario[a] |
|---|---|---|
| **OECD** | **0.8** | **0.4** |
| Americas | 0.8 | 0.7 |
| United States | 0.8 | 0.7 |
| Europe | 0.5 | 0.2 |
| Asia | 1.3 | 0.5 |
| **Non-OECD** | **2.4** | **2.5** |
| Europe and Eurasia | 0.3 | 0.7 |
| China | 3.1 | 2.7 |
| India | 2.9 | 4.2 |
| Other Non-OECD Asia | 2.6 | 2.6 |
| Middle East | 3.2 | 2.1 |
| Africa | 2.5 | 3.0 |
| Americas | 1.0 | 2.2 |
| **World** | **1.7** | **1.5** |

[a]IEA growth rates calculated from 2013-20.
Sources: **IEO2016:** U.S. Energy Information Administration, World Energy Projection System Plus, run IEO2016-reference_final_2016.02.19_115008. **IEA:** International Energy Agency, *World Energy Outlook 2015* (Paris, France: November 2015), pp. 580–659, Current Policies Scenario.

### Projections to 2020

In the IEO2016 Reference case, world total energy consumption increases by an average of 1.7%/year from 2012 to 2020, compared with 1.8%/year from 2013 to 2020 in the IEA Current Policies Scenario (Table K1). For the OECD region, total energy consumption increases by an average of 0.8%/year from 2012 to 2020 in the IEO2016 Reference case, compared with 0.4%/year from 2013 to 2020 in the IEA Current Policies Scenario. For the OECD Americas, the two outlooks have similar projected growth rates: total energy consumption increases by 0.8%/year from 2012 to 2020 in the IEO2016 Reference case and by 0.7%/year in the IEA Current Policies Scenario. However, for both the OECD Europe and OECD Asia regions, energy consumption growth rates in the IEO2016 Reference case are more than twice the rates projected in the IEA Current Policies Scenario.

For the non-OECD region as a whole, projections for growth in total energy consumption are about the same in the IEO2016 Reference case and the IEA Current Policies Scenario, at 2.4%/year and 2.5%/year, respectively. However, there are notable differences for some subregions, with IEA projecting more rapid growth for India, Africa, the non-OECD Americas, and non-OECD Europe and Eurasia. For India, growth in total energy consumption averages 4.2%/year from 2013 to 2020 in the IEA Current Policies Scenario, compared with 2.9%/year from 2012 to 2020 in the IEO2016 Reference case. For Africa, the respective growth rates are 3.0%/year from 2013

[1]International Energy Agency, *World Energy Outlook 2015,* Chapter 1: Introduction and Scope (Paris, France: November 2015), p. 31.
[2]All prices are reported in real, inflation-adjusted 2013 U.S. dollars.
[3]For this comparison, IEO2016 total world demand for liquid fuels was adjusted to report ethanol on a motor gasoline equivalent basis, as in the IEA outlook. Ethanol demand was adjusted by multiplying ethanol volumes projected for 2020 and 2040 by 2/3.

to 2020 (IEA) and 2.5%/year from 2012 to 2020 (IEO2016); for the non-OECD Americas they are 2.2%/year (IEA) and 1.0%/year (IEO2016); and for non-OECD Europe and Eurasia they are 0.7%/year (IEA) and 0.3%/year (IEO2016). China and the Middle East are the only non-OECD regions for which the IEO2016 projections for energy consumption growth through 2020 are higher than the IEA projections. For China, the respective growth rates are 2.7%/year (IEA) and 3.1%/year (IEO2016), and for the Middle East they are 2.1%/year (IEA) and 3.2%/year (IEO2016).

The projections vary not only with respect to levels of energy demand but also with respect to the mix of primary energy inputs. For the 2012–20 period, the IEO2016 Reference case projects slower growth in the use of natural gas and nuclear energy and more rapid growth for liquid fuels and renewable energy than projected in the IEA Current Policies Scenario (Table K2). The two projections are similar for coal consumption (average growth of 1.2%/year in the IEO2016 Reference case and 1.1%/year in the IEA Current Policies Scenario) and for liquid fuels consumption (average growth of 1.3%/year in the IEO2016 Reference case and 1.1%/year in the IEA Current Policies Scenario). For world natural gas consumption, the IEO2016 Reference case projects average growth of 1.3%/year from 2012 to 2020, compared with 1.6%/year in the IEA Current Policies Scenario.

For renewable energy consumption, however, the IEO2016 Reference case projects average growth of 4.0%/year from 2012 to 2020, and the IEA Current Policies Scenario projects average growth of 2.4%/year (adjusted for this comparison by removing biofuels from total renewables and reporting them as liquid fuels, consistent with EIA's treatment of biofuels). The differences are, in large part, a result of IEA's inclusion of traditional, nonmarketed biomass in its renewable energy projections, whereas the IEO2016 projections do not include consumption of nonmarketed renewable fuels, which is not likely to expand significantly, because developing countries tend to move away from traditional fuels to commercial fuels as their energy infrastructures and standards of living increase. Still, consumption of traditional fuels in some developing countries is estimated to be quite large, with effects on total renewable energy use that would tend to mask any growth in the consumption of energy from marketed, commercial renewable sources—particularly, wind and other nonhydroelectric renewables.

## Projections to 2040

For the period from 2020 to 2040, both the IEO2016 Reference case and the IEA Current Policies Scenario project slowing growth in world energy demand, with increases in total world energy consumption averaging 1.3%/year in both projections (Table K3). Among the OECD regions, the rates of energy demand growth in the IEO2016 Reference case generally exceed those in the IEA Current Policies Scenario. For example, the average annual growth rates for energy consumption in both the OECD Europe and OECD Asia regions in the IEO2016 Reference case are about three times those in the IEA Current Policies Scenario. However, for U.S. energy consumption the 2020–40 growth rates in the IEO2016 Reference case and the IEA Current Policies Scenario are similar, at 0.2%/year and 0.3%/year, respectively.

For total non-OECD energy consumption, the IEO2016 Reference case and the IEA Current Policies Scenario project similar overall growth rates in energy demand from 2020 to 2040. Even at the regional level, the IEO2016 and IEA Current Policies Scenario show considerable agreement (growth rates that differ by less than 0.1 percentage points) in the long term for China, India, and the Middle East. The largest differences are for non-OECD Europe and Eurasia (0.5%/year in the

### Table K2. Comparison of IEO2016 and IEA world energy consumption growth rates by energy source, 2012–20 (average annual percent growth)

| Energy source | IEO2016 | IEA[a] |
|---|---|---|
| Petroleum and other liquids | 1.3 | 1.1 |
| Natural gas | 1.3 | 1.6 |
| Coal | 1.2 | 1.1 |
| Nuclear | 3.0 | 3.6 |
| Renewables | 4.0 | 2.4 |
| **Total** | **1.7** | **1.5** |

[a]IEA growth rates calculated from 2013–20.
Sources: **IEO2016:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008. **IEA:** International Energy Agency, *World Energy Outlook 2015* (Paris, France: November 2015), pp. 580–659, Current Policies Scenario.

### Table K3. Comparison of IEO2016 and IEA world energy consumption growth rates by region, 2020–40 (average annual percent growth)

| Region | IEO2016 | IEA |
|---|---|---|
| OECD | **0.5** | **0.2** |
| Americas | 0.5 | 0.4 |
| United States | 0.2 | 0.3 |
| Europe | 0.6 | 0.2 |
| Asia | 0.6 | 0.2 |
| Non-OECD | **1.8** | **1.9** |
| Europe and Eurasia | 0.5 | 1.0 |
| China | 1.3 | 1.4 |
| India | 3.3 | 3.2 |
| Other Non-OECD Asia | 2.5 | 2.3 |
| Middle East | 2.1 | 2.2 |
| Africa | 2.6 | 2.2 |
| Americas | 1.7 | 1.9 |
| World | **1.3** | **1.3** |

Sources: **IEO2016:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008. **IEA:** International Energy Agency, *World Energy Outlook 2015* (Paris, France: November 2015), pp. 580–659, Current Policies Scenario.

IEO2016 Reference case, 1.0%/year in the IEA Current Policies Scenario) and Africa (2.6%/year in the IEO2016 Reference case, 2.2%/year in the IEA Current Policies Scenario).

For the 2020–40 period, the most noticeable differences between the IEO2016 Reference case and IEA Current Policies Scenario projections are for total world coal consumption (Table K4). In the IEA projection, the average growth rate for world coal consumption increases from 1.1%/year in the 2013–20 period to 1.4%/year in the 2020–40 period. In contrast, the growth rate for coal consumption in the IEO2016 Reference case slows in the later years, from an average of 1.2%/year from 2012 to 2020 to 0.3%/year from 2020 to 2040. For nuclear power, renewable energy, and natural gas consumption, the IEO2016 Reference case shows more rapid increases in consumption than in the IEA Current Policies Scenario, as energy consumers (particularly in China) use those fuels to displace coal in the longer term.

## Comparisons with IEO2013

The IEO2016 Reference case projection for world total energy consumption in 2020 is nearly the same as the IEO2013 Reference case projection. For total world energy consumption in 2020, the IEO2016 Reference case projection is 629 quadrillion Btu, as compared with 630 quadrillion Btu in the IEO2013 Reference case (Table K5). For total OECD energy consumption in 2020, the difference between the IEO2016 and IEO2013 Reference case projections is less than 1 quadrillion Btu. There are, however, larger differences between the IEO2016 and IEO2013 Reference case projections for the non-OECD regions and countries, given the larger uncertainty associated with the non-OECD countries.

The largest difference between the IEO2016 and IEO2013 Reference case projections for the non-OECD region in 2020 is for China's total energy consumption. In the IEO2016 Reference case, total energy consumption in China is 12 quadrillion Btu (7%) lower than the 2020 projection for China in IEO2013, largely because the IEO2016 Reference case projection for China's economic growth is lower than the IEO2013 projection, which did not anticipate the extent of the slowdown in China's economic growth in 2014 and 2015. In the IEO2013 Reference case, China's GDP growth from 2012 to 2020 was projected to average 7.3%/year, as compared with an average of 6.2%/year in the IEO2016 Reference case.

In the IEO2016 Reference case projection, lower energy consumption in China is offset by higher energy consumption in Africa, the Middle East, and other non-OECD Asia (excluding China and India). For Africa and other non-OECD Asia, roughly one-half of the difference between the IEO2013 and IEO2016 projections for 2020 results from differences in the energy consumption estimates for 2012 (which was a projection year in IEO2013). The IEO2013 Reference case projection for Africa's total energy consumption in 2012 was 18.9 quadrillion Btu—nearly 14% lower than the reported historical total in IEO2016. For the Middle East, higher GDP growth assumptions in the IEO2016 Reference case (4.0%/year from 2012 to 2020, as compared with 3.6%/year in IEO2013) account for the differences between the projections. In 2040, China's total energy consumption is 30 quadrillion Btu (14%) lower in the IEO2016 Reference case than projected in the IEO2013 Reference case, largely as a result of different assumptions for China's future economic growth. In the IEO2016 Reference case, China's GDP growth averages 4.1%/year from 2020 to 2040, as compared with 4.8%/year in the IEO2013 Reference case.

For the Middle East and Africa, energy consumption increases more rapidly in the IEO2016 Reference case than was projected in the IEO2013 Reference case. For the Middle East, GDP growth in the IEO2013 Reference case averaged 1.5%/year from 2020 to 2040, compared with 3.6%/year in the IEO2016 Reference case, and as a result the region's total energy consumption in 2040 is 13 quadrillion Btu higher in the IEO2016 Reference case than in the IEO2013 Reference case. In Africa, GDP growth averaged 4.7%/year from 2020 to 2040 in the IEO2013 Reference case, compared with 4.9%/year in the IEO2016 reference case.

**Table K4. Comparison of IEO2016 and IEA world energy consumption growth rates by energy source, 2020–40 (average annual percent growth)**

| Energy source | IEO2016 Reference Case | IEA Current Policies Scenario |
|---|---|---|
| Petroleum and other liquids | 0.9 | 0.9 |
| Natural gas | 2.1 | 1.8 |
| Coal | 0.3 | 1.4 |
| Nuclear | 2.0 | 1.1 |
| Renewables | 2.1 | 1.5 |
| **Total** | **1.3** | **1.3** |

Sources: **IEO2016:** U.S. Energy Information Administration, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008. **IEA:** International Energy Agency, *World Energy Outlook 2015* (Paris, France: November 2015), pp. 580–659, Current Policies Scenario.

The IEO2016 and IEO2013 Reference case projections also differ in terms of the mix of energy resources consumed. Consumption of liquid fuels, natural gas, and renewable energy in 2020 is higher, and consumption of coal and nuclear power is lower, in IEO2016 than in IEO2013 (Table K6). The largest difference is in projected coal use, which in the IEO2016 Reference case is 12 quadrillion Btu lower in 2020 and 39 quadrillion Btu lower in 2040 than projected in the IEO2013 Reference case, with virtually all of the difference attributable to the projections for China, where lower economic growth in IEO2016 reduces demand in general, and policies aimed at reducing the use of coal to address environmental issues result in lower demand. The IEO2016 Reference case projection for nuclear power consumption in 2040 is 11 quadrillion Btu lower than projected in IEO2013. Consumption in 2040 is lower in IEO2016 than in IEO2013 for every region with existing nuclear power plants, except for the Middle East and non-OECD Americas. In many regions, efforts to increase renewable energy and/or more plentiful natural gas supplies reduce the need to construct nuclear power plants.

## Table K5. Total energy consumption in the IEO2016 and IEO2013 Reference cases, 2020 and 2040 (quadrillion Btu)

| | 2020 | | 2040 | | Difference, IEO2013 vs. IEO2016 | |
|---|---|---|---|---|---|---|
| Region | IEO2016 | IEO2013 | IEO2016 | IEO2013 | 2020 | 2040 |
| **OECD** | **254** | **255** | **282** | **285** | **-1** | **-2** |
| **Americas** | **126** | **126** | **138** | **144** | **0** | **-5** |
| United States | 101 | 100 | 106 | 107 | 0 | -1 |
| Canada | 15 | 15 | 18 | 18 | 0 | 0 |
| Mexico and Chile | 10 | 11 | 14 | 18 | -1 | -4 |
| **Europe** | **85** | **85** | **96** | **95** | **-1** | **1** |
| **Asia** | **43** | **43** | **48** | **46** | **0** | **2** |
| Japan | 22 | 23 | 21 | 22 | -1 | -1 |
| South Korea | 14 | 13 | 17 | 16 | 1 | 1 |
| Australia and New Zealand | 8 | 7 | 10 | 8 | 0 | 2 |
| **Non-OECD** | **375** | **375** | **533** | **535** | **0** | **-2** |
| **Europe and Eurasia** | **52** | **53** | **58** | **67** | **-1** | **-10** |
| Russia | 33 | 33 | 35 | 41 | 0 | -6 |
| Other Non-OECD Europe and Eurasia | 19 | 20 | 23 | 27 | -1 | -3 |
| **Asia** | **223** | **230** | **322** | **337** | **8** | **15** |
| China | 147 | 159 | 190 | 220 | -12 | -30 |
| India | 33 | 32 | 62 | 55 | 1 | 7 |
| Other Non-OECD Asia | 43 | 39 | 70 | 63 | 3 | 7 |
| **Middle East** | **41** | **37** | **62** | **49** | **4** | **13** |
| **Africa** | **26** | **22** | **44** | **35** | **4** | **9** |
| **Americas** | **33** | **33** | **47** | **47** | **0** | **1** |
| Total World | **629** | **630** | **815** | **820** | **-1** | **-5** |

Sources: **IEO2013:** U.S. Energy Information Administration (EIA), *International Energy Outlook 2013,* DOE/EIA-0484(2013) (Washington, DC: July 2013). **IEO2016:** U.S. EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Table K6. Energy consumption by energy source in the IEO2016 and IEO2013 Reference cases, 2020 and 2040 (quadrillion Btu)

| | 2020 | | 2040 | | Difference, IEO2013 vs. IEO2016 | |
|---|---|---|---|---|---|---|
| Energy source | IEO2016 | IEO2013 | IEO2016 | IEO2013 | 2020 | 2040 |
| Petroleum and other liquids | 204 | 195 | 246 | 233 | 9 | 13 |
| Natural gas | 138 | 136 | 211 | 191 | 2 | 20 |
| Coal | 169 | 180 | 180 | 220 | -12 | -39 |
| Nuclear | 31 | 38 | 46 | 57 | -7 | -11 |
| Renewables | 87 | 81 | 131 | 119 | 6 | 12 |
| Total | **629** | **630** | **815** | **820** | **-1** | **-5** |

Note: The IEO2016 Reference case does not include the U.S. Clean Power Plan (CPP). If the U.S. CPP were included in the IEO2016 projections, world energy consumption in 2020 would be 2 quadrillion Btu lower in 2020 (coal consumption would be 4 quadrillion Btu lower) and world energy consumption in 2040 would be 1 quadrillion Btu lower (coal consumption would be 4 quadrillion Btu lower).
Sources: **IEO2013:** U.S. Energy Information Administration (EIA), *International Energy Outlook 2013,* DOE/EIA-0484(2013) (Washington, DC: July 2013). **IEO2016:** U.S. EIA, World Energy Projection System Plus (2016), run IEO2016-reference_final_2016.02.19_115008.

## Appendix L

# Models used to generate the IEO2016 projections

The IEO2016 projections of world energy consumption and supply were generated from EIA's World Energy Projection System Plus (WEPS+) model. WEPS+ consists of a system of individual sectoral energy models, using an integrated iterative solution process that allows for convergence of consumption and prices to an equilibrium solution. It is used to build the Reference case energy projections, as well as alternative energy projections based on different assumptions for GDP growth and fossil fuel prices. It can also be used to perform other analyses.

WEPS+ produces projections for 16 regions or countries of the world, including: OECD Americas (United States, Canada, and Mexico/Chile), OECD Europe, OECD Asia (Japan, South Korea, and Australia/New Zealand), Russia, other non-OECD Europe and Eurasia, China, India, other non-OECD Asia, Middle East, Africa, Brazil, and other non-OECD Americas. Currently, the projections extend to 2040.

The WEPS+ platform allows the various individual models to communicate through a common, shared database and provides a comprehensive central series of output reports for analysis. In the individual models, the detail also extends to the subsector level. In WEPS+, the end-use demand models (residential, commercial, industrial, and transportation) project consumption of the key primary energy sources: several petroleum products, other liquid fuels, natural gas, coal, nuclear power, hydropower, wind, geothermal, solar, and other renewable sources (biomass, waste, and tide/wave/ocean). These models also provide intermediate consumption projections for electricity in the end-use demand sectors.

The end-use model projections generally depend on retail supply prices, economic activity as represented by GDP (or gross output in the industrial sector), and population. The transformation models (power generation and district heat) satisfy electricity and heat requirements and also project consumption of primary energy sources at resulting price levels. The supply models (petroleum and other liquid fuels, natural gas, and coal) generate supply and wholesale price projections for the key supply sources corresponding to the primary consumption sources. The refinery model makes retail price projections for a variety of petroleum products corresponding to the world oil price. The main model in the WEPS+ system monitors the convergence sequence for all the models and projects energy-related carbon dioxide emissions from fossil fuels (including emissions from the use of petrochemical feedstocks but excluding flared natural gas) at the regional level.

The Reference case reflects the underlying relationships incorporated in the complete set of models interacting in supply/demand relationships communicated through macroeconomic variables, prices, and consumption. The system of models is run iteratively to a point at which prices and consumption have converged to reasonable equilibrium. Accumulated knowledge from the results of other complex models that focus on specific supply or demand issues, and analysts' expert judgments, also are taken into account and incorporated into the final projections. After the Reference case has been established, WEPS+ is used to run alternative scenarios that reflect different assumptions about future economic growth and world oil prices.

Several improvements were made throughout the WEPS+ modeling system for IEO2016, and with the exception of the transportation sector model, the models themselves are essentially unchanged from those used for IEO2013 and IEO2014. (IEO2014 included projections only for petroleum and other liquid fuels.) The model enhancements for IEO2016 include the incorporation of a new International Transportation Energy Demand Determinants (ITEDD) model, improvements to the macroeconomic model and to the world liquid fuels supply model, improvements to the methodology for projecting renewable energy electricity generation and installed generating capacity, and implementation of an "unspecified sector" to reconcile differences between aggregate published historical data (mostly liquid fuels) and model estimates of sectoral energy use (primarily in the transportation and industrial sectors).

The new ITEDD model:

- Uses a bottoms-up approach to estimate demand for transportation energy by mode (road, rail, air, and marine) and vehicle type (light-duty vehicles, freight trucks, passenger rail, etc.)
- Estimates transportation energy consumption by fuel and region
- Estimates vehicle stocks by vehicle type and region.

For the Oxford Economics Global Economic Model, model improvements include:

- Expanding energy coverage to allow linkages of all energy prices (coal, natural gas, and refined products) in addition to oil
- Adding a substantial number of variables to be used by other WEPS+ models, as compared to IEO2013 and IEO2014
- Improving the mechanics of the transfer system between WEPS+ and Oxford through expansion of its capabilities and further testing.

The improved methodology for projecting renewable energy sources incorporates a systematic process for rating the prospects for achievement of stated renewable energy targets in different countries and regions by:

- Using historical data on countries' prior success in meeting renewable policy objectives, accounting for both the ambition and extent of fulfillment of targets

- Using indicators of each country's financial capability to build new projects
- Assessing market pricing to incentivize development of renewable projects
- Applying a time-dependent decay function to initial estimations to adjust probabilities according to how far into the future the target has been specified.

The methodology for deriving petroleum and other liquids supplies within the Generate World Oil Balance application (described below) incorporates a new tool to improve the validation of analysts' expectations for long-term oil production rates. The new tool takes into account the resource base, in the form of existing oil field production declines, potential for new development in known fields, and resource assessments of oil yet to be found. Those volumes are compared to the analysts' expectations. Estimates of the uncertainties in the three different types of resource tranches also are considered when the analysts' long-term expectations are validated.

The Oxford Economics Global Economic Model (GEM) and Global Industry Model (GIM) are used to generate projections of gross domestic product (GDP) and gross output for the various IEO2016 countries and regions and their respective industrial sectors, given energy inputs from WEPS+. The theoretical structure of GEM differentiates between the short-term and long-term projections for each country, with extensive coverage of the links among different economies. GEM produces GDP outputs for use with WEPS+ and also provides drivers for GIM. The structure of GIM, which calculates gross output in the IEO sectors for each country or region in WEPS+, is based on input-output relationships. It calculates gross output in the IEO sectors for each country or region in WEPS+.

The Generate World Oil Balance (GWOB) application is used to create a "bottom-up" projection of world liquids supply—based on current production capacity, planned future additions to capacity, resource data, geopolitical constraints, and prices—and to generate three production scenarios. The scenarios (Oil Price cases) are developed through an iterative process of examining demand levels at given prices and considering price and income sensitivity on both the demand and supply sides of the equation. Data from EIA's Short-Term Energy Outlook are integrated to ensure consistency between short-term and long-term modeling efforts. Projections of crude oil production are tested against reserve and resource estimates. Projections of other liquids production are based on exogenous analysis.

Ten major streams of liquids production are tracked on a volume basis in two categories. Crude and lease condensate supply includes: (1) reservoired oil—often referred to as "conventional oil" in the trade press, (2) tight oil—including shale oil, (3) extra-heavy crude oil, and (4) bitumen (oil sands, either diluted or upgraded). Other liquids supply includes: (5) natural gas plant liquids (NGPL), (6) biofuels (including ethanol, biodiesel, and biomass-to-liquids [BTL]), (7) gas-to-liquids (GTL), (8) coal-to-liquids (CTL), (9) kerogen (oil shale), and (10) refinery gain.

The terms *biofuels, GTL, CTL,* and *kerogen* are used in the text of the report because they are common terms. In the appendix tables, a more uniform nomenclature is employed: *liquids from renewable sources, liquids from natural gas, liquids from coal,* and *liquids from kerogen,* respectively. All liquid fuels are reported in physical volumes, unless otherwise stated.

The IEO2016 projections of global natural gas production and trade were generated from EIA's International Natural Gas Model (INGM), a tool that estimates natural gas production, demand, and international trade. The INGM combines estimates of natural gas reserves, natural gas resources and resource extraction costs, energy demand, and transportation costs and capacity in order to estimate future production, consumption, and prices of natural gas.

INGM incorporates regional energy consumption projections by fuel from the WEPS+ model, as well as more detailed U.S. projections from EIA's National Energy Modeling System (NEMS), which is used to generate U.S. energy projections for the Annual Energy Outlook. An iterative process between INGM and WEPS+ is used to balance world natural gas markets, with INGM providing supply curves to WEPS+ and receiving demand estimates developed by WEPS+. INGM uses estimates of regional natural gas demand from NEMS for the United States, rather than those computed as part of the WEPS+ output, so that the final output for the United States is consistent with AEO projections.

## Appendix M
# Regional definitions

The 16 basic country groupings used in this report are defined as follows:

**Region 1:** United States.

**Region 2:** Canada.

**Region 3:** Mexico/Chile.

**Region 4—OECD Europe:** Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom. (Note: Israel is included in OECD Europe for statistical purposes.)

**Region 5:** Japan.

**Region 6:** South Korea.

**Region 7:** Australia/New Zealand.

**Region 8:** Russia.

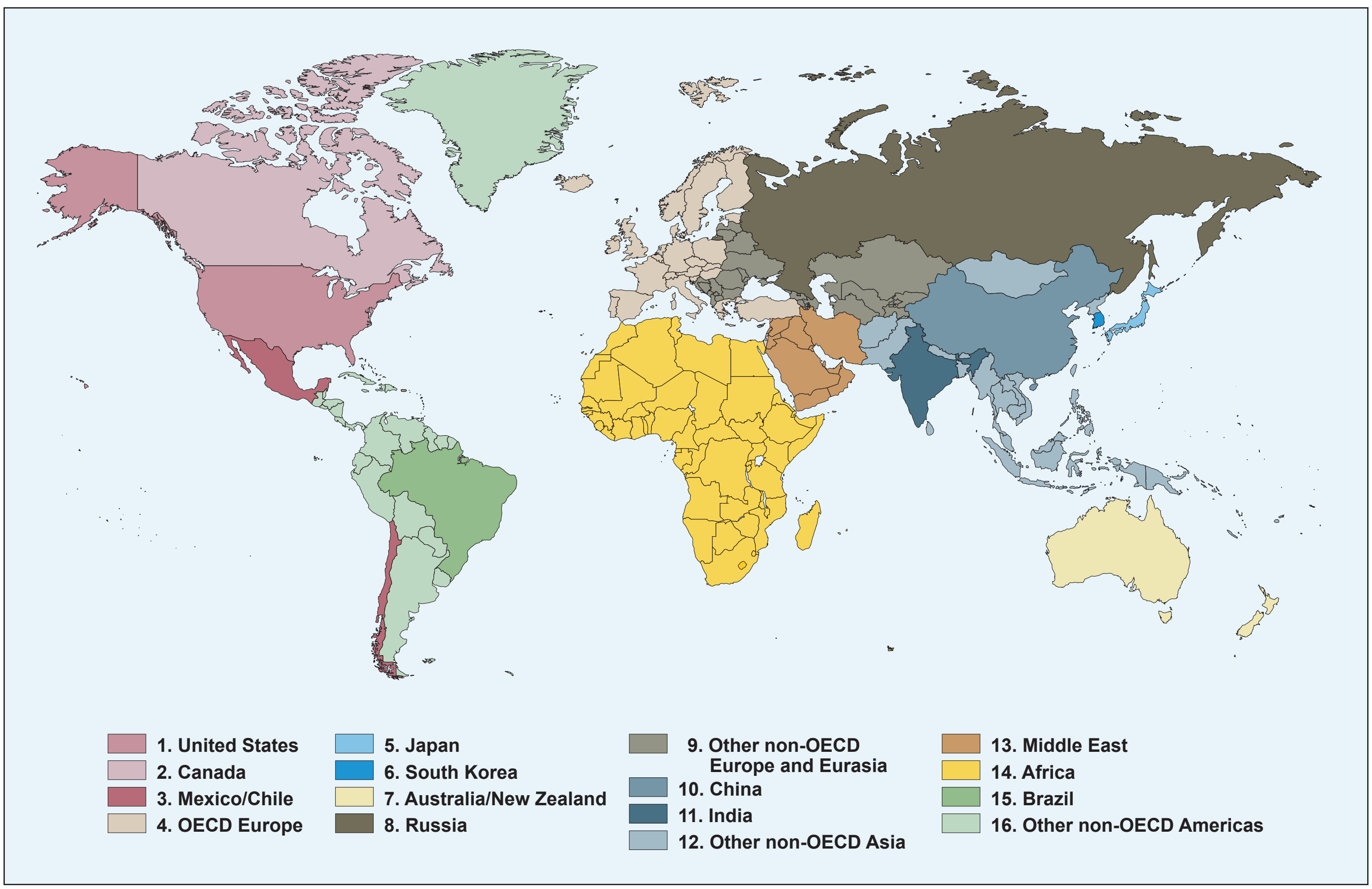
**Region 9—Other non-OECD Europe and Eurasia:** Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Faroe Islands, Georgia, Gibraltar, Kazakhstan, Kosovo, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malta, Moldova, Montenegro, Romania, Serbia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

**Region 10:** China.

**Region 11:** India.

**Region 12—Other non-OECD Asia:** Afghanistan, American Samoa, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), Cook Islands, Fiji, French Polynesia, Guam, Hawaiian Trade Zone, Hong Kong, Indonesia, Kiribati, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Timor-Leste (East Timor), Tonga, U.S. Pacific Islands, Vanuatu, Vietnam, Wake Islands.

### Figure M1. Map of the six basic country groupings




Source: Energy Information Administration, Office of Energy Analysis.

**Region 13—Middle East:** Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestinian Territories, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen.

**Region 14—Africa:** Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa), Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, St. Helena, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, Zimbabwe.

**Region 15:** Brazil.

**Region 16—Other non-OECD Americas:** Antarctica, Antigua and Barbuda, Argentina, Aruba, The Bahamas, Barbados, Belize, Bermuda, Bolivia, British Virgin Islands, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Greenland, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Pierre and Miquelon, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, U.S. Virgin Islands, Venezuela.