



Independent Statistics & Analysis

U.S. Energy Information
Administration

International Energy Outlook Executive Summary

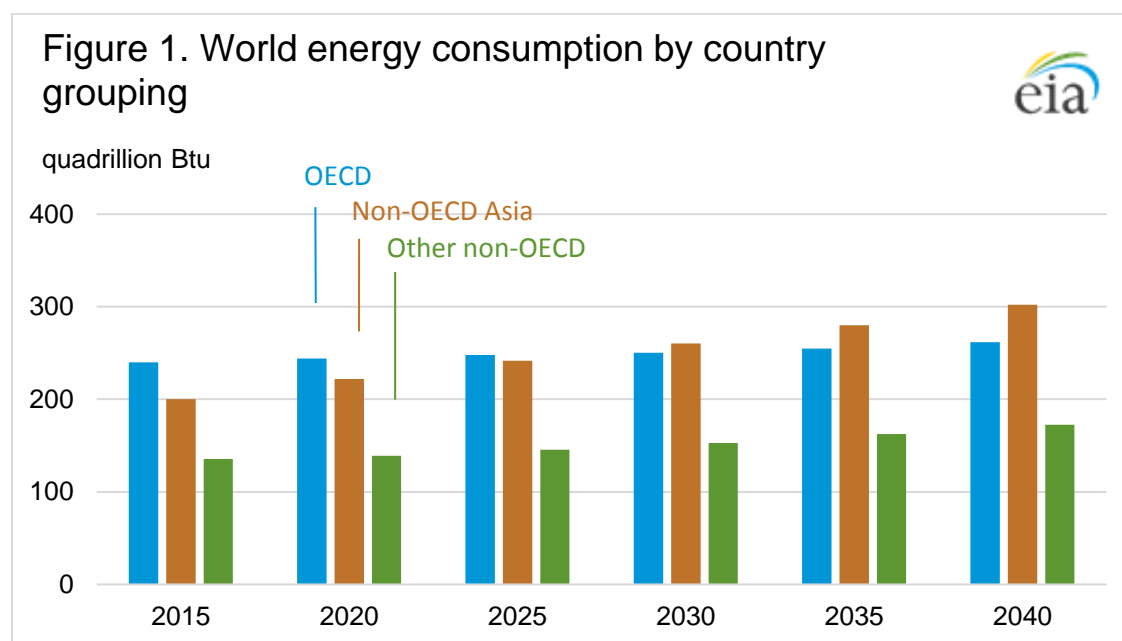
September 2017



This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the United States Government. The views in this report therefore should not be construed as representing those of the U.S. Department of Energy or other federal agencies.

Executive summary

In the *International Energy Outlook 2017* (IEO2017) Reference case, total world energy consumption rises from 575 quadrillion British thermal units (Btu) in 2015 to 736 quadrillion Btu in 2040, an increase of 28%. Most of the world's energy growth will occur in countries outside of the Organization for Economic Cooperation and Development (OECD) ^[1], where strong, long-term economic growth drives increasing demand for energy. Non-OECD Asia (including China and India) alone accounts for more than half of the world's total increase in energy consumption over the 2015 to 2040 projection period. By 2040, energy use in non-OECD Asia exceeds that of the entire OECD by 41 quadrillion Btu in the IEO2017 Reference case (Figure 1).



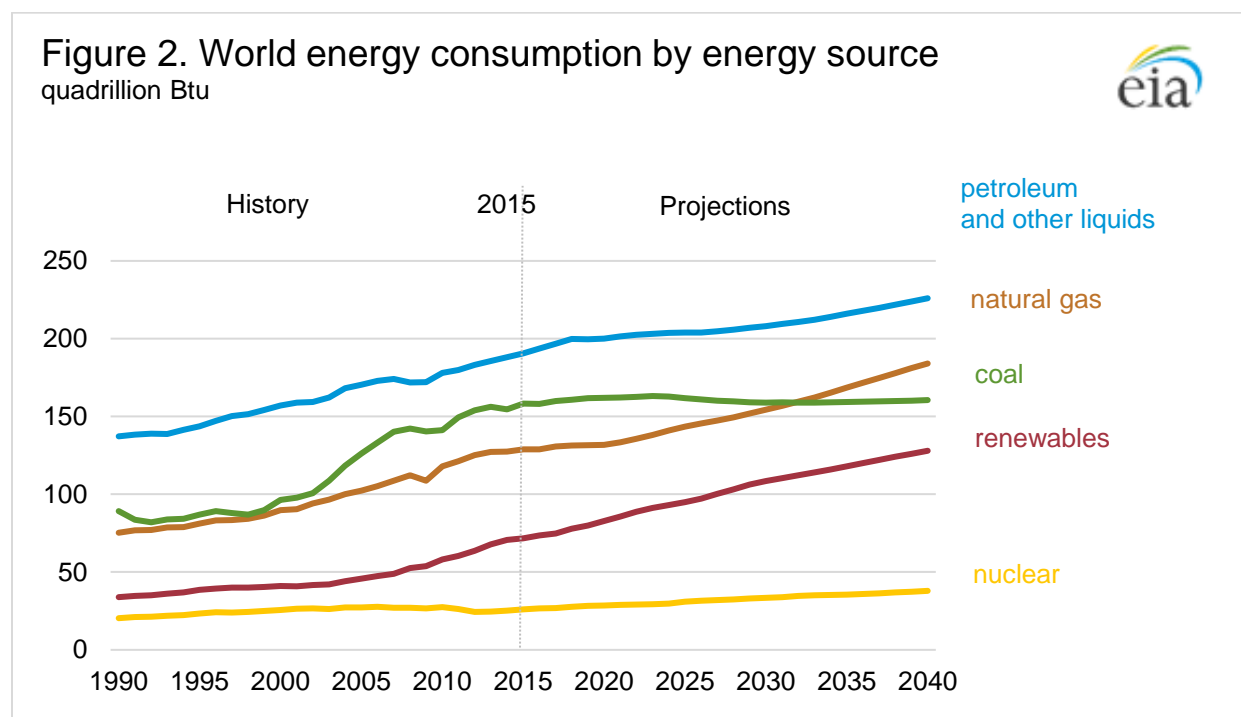
Economic growth—as measured by gross domestic product (GDP)—is a key determinant in the growth of energy demand. The world's GDP (expressed in purchasing power parity terms) rises by 3.0%/year from 2015 to 2040. The fastest rates of growth are projected for the emerging, non-OECD regions, where combined GDP increases by 3.8%/year, driving the fast-paced growth in future energy consumption among those nations. In the OECD regions, GDP grows at a much slower rate of 1.7%/year between 2015 and 2040, at least in part, because of slow or declining population growth in those regions.

¹For consistency, OECD includes all members of the organization as of June 1, 2016, throughout all the time series included in this report. OECD member countries as of June 1, 2016, are 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. Latvia became a member of the OECD on July 1, 2016, and its membership is not yet reflected in the IEO projections.

World energy markets by fuel type

In the long term, the IEO2017 Reference case projects increased world consumption of marketed energy from all fuel sources—except coal, where demand is essentially flat—through 2040 (Figure 2).

Renewables are the world's fastest-growing energy source, with consumption increasing by an average 2.3%/year between 2015 and 2040. The world's second fastest-growing source of energy is nuclear power, with consumption increasing by 1.5%/year over that period.



Although consumption of nonfossil fuels is expected to grow faster than fossil fuels, fossil fuels still account for 77% of energy use in 2040. Natural gas is the fastest-growing fossil fuel in the projections. Global natural gas consumption increases by 1.4%/year. Abundant natural gas resources and rising production—including supplies of tight gas, shale gas, and coalbed methane—contribute to the strong competitive position of natural gas. Liquid fuels—mostly petroleum-based—remain the largest source of world energy consumption. However, the liquids share of world marketed energy consumption falls from 33% in 2015 to 31% in 2040, as oil prices rise steadily, leading many energy users to adopt more energy-efficient technologies and to switch away from liquid fuels when feasible.

Compared with the strong growth in coal use in the 2000s, worldwide coal use remains flat in the IEO2017 Reference case [2]. Coal is increasingly replaced by natural gas, renewables, and nuclear power (in the case of China) for electric power generation, and demand for coal also weakens for industrial processes. China is the world's largest consumer of coal, but coal use is projected to decline in China by 0.6%/year from 2015 to 2040, and in the combined OECD countries coal also declines by 0.6%/year over

² The IEO2017 Reference case projections include the impacts of the U.S. Clean Power Plan (CPP) regulations. According to EIA's analysis, U.S. coal consumption would be 15.2 quadrillion Btu in 2040 without the CPP, relative to the IEO2017 Reference case projection of 10.6 quadrillion Btu.

that same period. With coal consumption in India and other nations in non-OECD Asia growing over the projection period, worldwide coal consumption is not as low as it would otherwise be in 2040. The coal share of total world energy consumption declines significantly over the projection period, from 27% in 2015 to 22% in 2040.

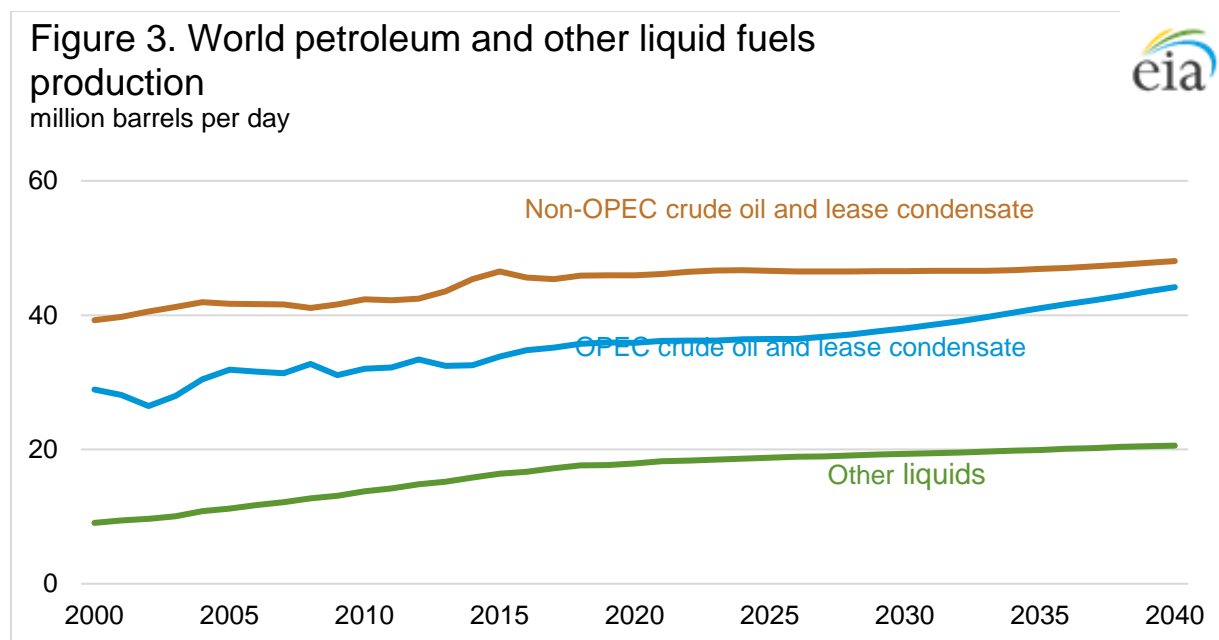
Liquid fuels

World use of petroleum and other liquid fuels grows from 95 million barrels per day (b/d) in 2015 to 104 million b/d in 2030 and to 113 million b/d in 2040. Most of the growth in liquid fuels consumption is in the transportation and industrial sectors. In the transportation sector, liquid fuels continue to provide most of the energy consumed. Although advances in nonliquids-based transportation technologies are anticipated, they do not fully offset the rising demand for transportation services worldwide. Liquid fuels consumed for transportation increases by an average of 0.7%/year from 2015 to 2040. The transportation sector accounts for 60% 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 throughout the projection. The use of liquids declines for electric power generation.

To satisfy the increase in world liquids demand in the IEO2017 Reference case, petroleum and other liquid fuels ^[3] production increases by 16.1 million b/d from 2015 to 2040. The Reference case assumes that countries in the Organization of the Petroleum Exporting Countries (OPEC) will invest in incremental production capacity to maintain a 39%–44% 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 10.3 million b/d to the total increase in world liquids production, and crude oil and lease condensate volumes from non-OPEC countries add 1.6 million b/d (Figure 3).

The production of other liquid fuels grows by 4.2 million b/d between 2015 and 2040. Natural gas plant liquids and biofuels combined account for 97% of the increase in other liquids fuels production, and gas-to-liquids, coal-to-liquids, kerogen (shale oil), and refinery gain accounting for the remainder. Other liquids resources from both OPEC and non-OPEC sources grow on average by 0.9%/year in the IEO2017 Reference case, and they remain a relatively small share of total world petroleum and other liquid fuels production. In 2015, other liquids accounted for about 17% of total liquid fuels production; that share is projected to increase modestly to 18% in 2040.

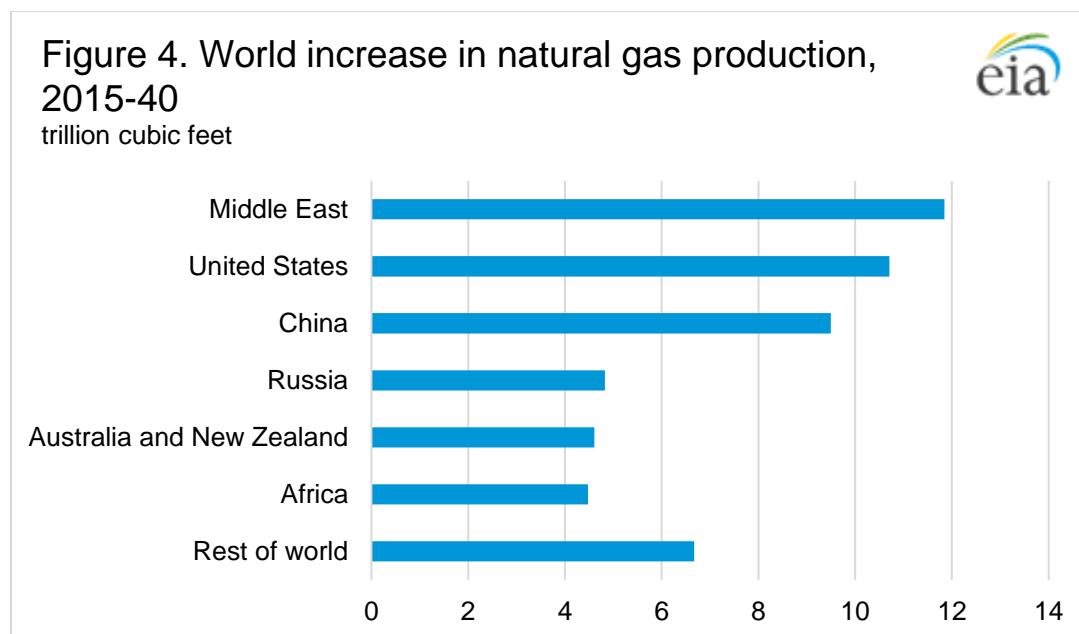
³Petroleum production is composed of crude oil and lease condensate, including tight oil, shale oil extra-heavy crude oil, field condensate, and bitumen. Other liquid fuels include natural gas plant liquids (NGPL), biofuels, gas-to-liquids (GTL), coal-to-liquids (CTL), kerogen, and refinery gain.



Natural gas

Worldwide natural gas consumption is projected to increase from 124 trillion cubic feet (Tcf) in 2015 to 177 Tcf in 2040 in the IEO2017 Reference case. By energy source, natural gas accounts for the largest increase in world primary energy consumption, second only to renewable energy sources. Abundant natural gas resources and rising 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 the industrial sector. In the power sector, natural gas is an attractive choice for new generating plants because of its relative fuel efficiency. Natural gas also burns more cleanly 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.

To meet the growth in natural gas demand projected in the IEO2017 Reference case, the world's natural gas producers increase supplies by 42% from 2015 to 2040. The largest increases in natural gas production from 2015 to 2040 occur in the Middle East (11.8 Tcf), China (9.5 Tcf), the United States (10.7 Tcf), and Russia (4.8 Tcf) (Figure 4). 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. In China, most growth in the long-term comes from the country's development of its shale resources, which are projected to account for more than half of its total natural gas production in 2040.

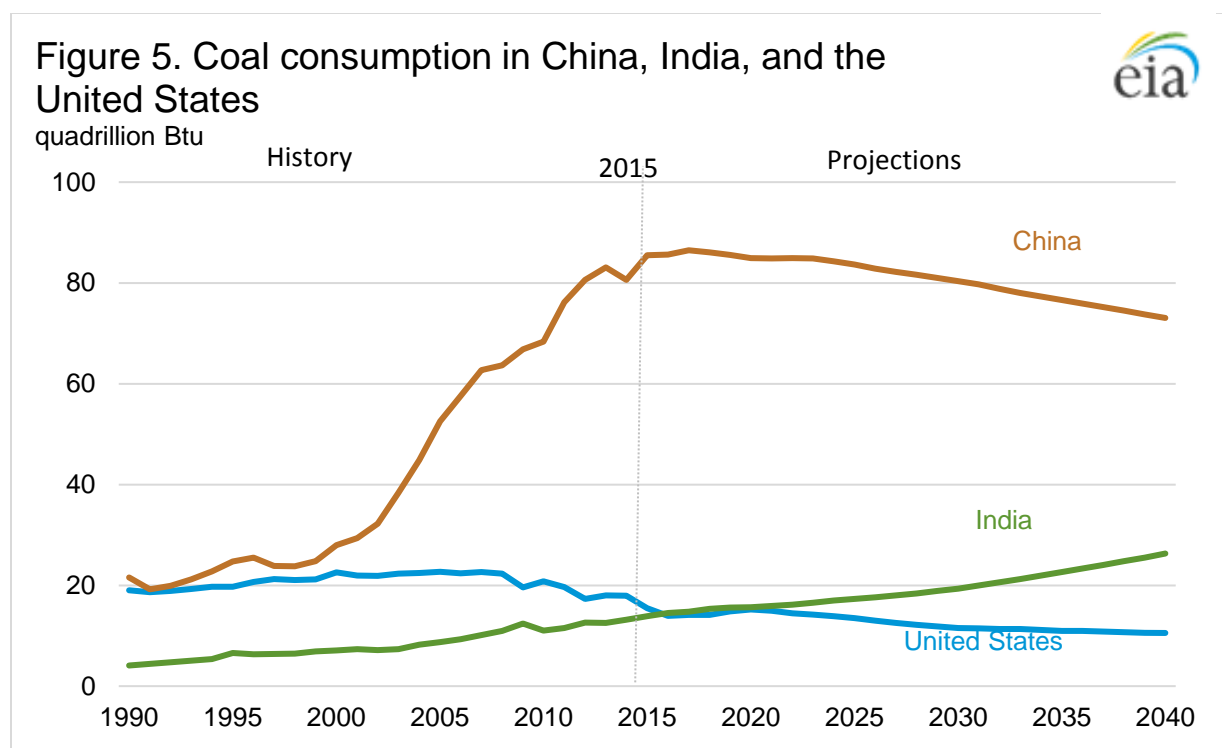


World natural gas trade, both by pipeline and by shipment in the form of liquefied natural gas (LNG), is poised to increase in the future. World LNG trade nearly triples, from about 12 Tcf in 2015 to around 31 Tcf in 2040. Most of the near-term increase in liquefaction occurs in Australia and North America, where a number of new liquefaction projects are planned or under construction, many of which will become operational within the next decade. U.S. LNG exports are projected to increase significantly over the projection period and to account for more than 60% of total U.S. natural gas exports in 2040.

In addition to the strong growth in LNG trade, natural gas trade by pipeline also increases in the IEO2017 Reference case, as several new long-distance pipelines are completed and existing infrastructure expands through 2040. Currently, the largest volumes of natural gas traded internationally by pipeline are in Europe (among a number of OECD and non-OECD countries) and in the Americas (between Canada and the United States). U.S. pipeline exports to Mexico are also becoming a more important component of trade in the Americas. Mexican pipeline imports from the United States have more than quadrupled since 2009, and they are expected to continue to increase over the next several years. By 2018, the United States becomes a net exporter of natural gas on an average annual basis, as pipeline exports to Mexico and LNG export volumes grow.

Coal

Worldwide consumption of coal remains flat throughout the IEO2017 Reference case, rising by 0.2%/year from 2015 to 2025, and then declining by 0.1%/year, reaching 161 quadrillion Btu in 2040. The top three coal-consuming countries are China, the United States, and India, which together account for around 70% of world coal use throughout the projection. China alone currently accounts for slightly more than half of the world's total coal consumption, but a slowing economy and plans to implement policies to address air pollution and climate change mean that coal use in China will decline over the projection period (Figure 5). Coal consumption projections in the IEO2017 Reference case include the impact of the Clean Power Plan (CPP) regulations in the United States. Excluding the CPP would increase world coal consumption to 165 quadrillion Btu in 2040, 4 quadrillion Btu higher than the Reference case.



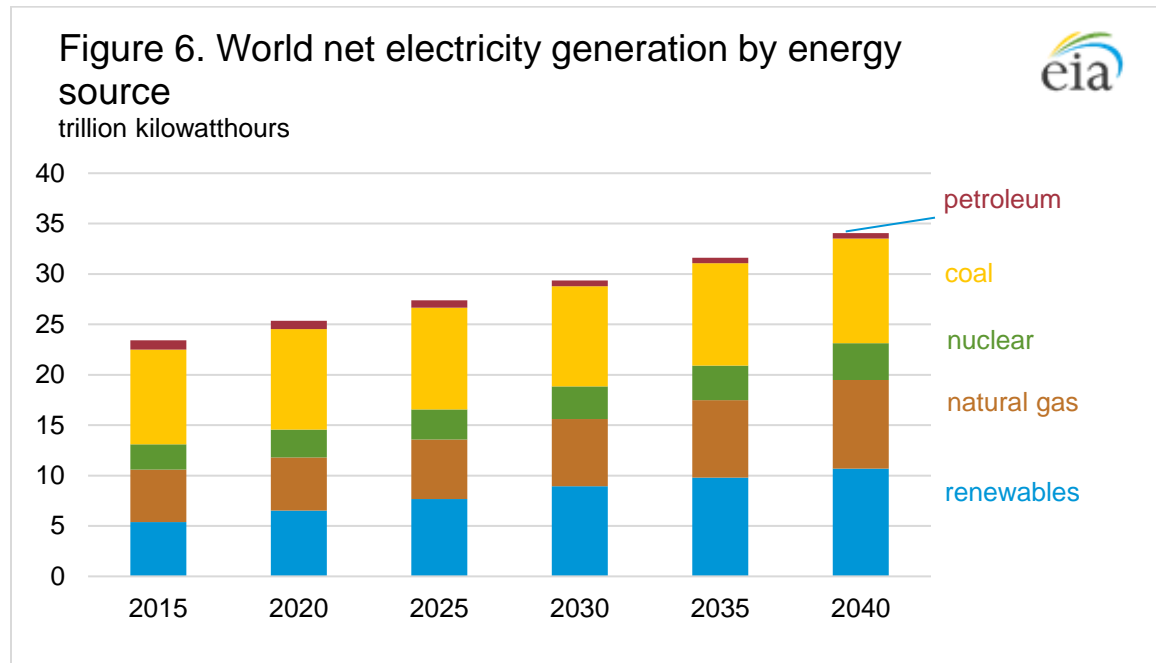
Global coal production is projected to remain at about 9 billion short tons from 2015 to 2040. Although the total world production volumes do not change over the projection, the producer profiles will likely change. China, the United States, and India are currently the world's largest coal producers, but India is the only one of the three countries where coal production increases in the IEO2017. Coal production in both China and the United States declines through 2040. In the projection, India's coal production overtakes U.S. production by 2025, and by 2040 India is projected to produce twice as much coal as the United States. Outside of India, coal production is expected to increase primarily in Australia, in nations of Asia outside of China and India, and in Africa. In the IEO2017 Reference case, China—currently the world's leading coal producer—will experience a decline in its market share of world coal production, which falls from 50% in 2015 to 42% in 2040, as India's share rises from 8% in 2015 to 14% in 2040.

Electricity

In the IEO2017 Reference case, world net electricity generation increases by 45%, rising from 23.4 trillion kilowatthours (kWh) in 2015 to 34.0 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 continue to evolve from isolated, noncompetitive grids to integrated national and international markets.

The strongest growth in electricity generation is projected to occur among the developing, non-OECD nations. Increases in electricity generation in non-OECD countries average 1.9%/year in the Reference case as rising living standards increase demand for home appliances and electronic devices, and 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 1.0%/year from 2015 to 2040 in the IEO2017 Reference case.

Long-term global prospects continue to improve for generation from renewable energy sources and natural gas (Figure 6). Renewables are the fastest-growing source of energy for electricity generation, with average increases of 2.8%/year from 2015 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 7% of total world generation in 2015; their share in 2040 is 15% in the IEO2017 Reference case, with more than half of the growth coming from wind power. After renewable energy sources, natural gas and nuclear power are the next fastest-growing sources of energy used to generate electricity.



Many countries, particularly those in the OECD, have enacted environmental policies and regulations intended to increase the pressure on electric power generators to reduce greenhouse gas emissions from electric power plants by decreasing the use of fossil fuels. As a result, the consistent role of coal as the least expensive fuel for electric power plants will change. Coal-fired net generation increases by 0.4%/year, compared to the 2.8%/year increase in projected renewable generation. By 2040, generation from renewable energy sources surpasses generation from coal on a worldwide basis.

Electricity generation from nuclear power worldwide increases from 2.5 trillion kWh in 2015 to 3.2 trillion kWh in 2030 and to 3.7 trillion kWh in 2040 in the IEO2017 Reference case. Concerns about energy security and greenhouse gas emissions support the development of new nuclear generating capacity, but reactor retirements and opposition from local populations keep nuclear from expanding in many parts of the world. Virtually all of the projected net expansion in world installed nuclear power capacity occurs in non-OECD countries, led by China's addition of 111 gigawatts (GW) of nuclear capacity from 2015 to 2040.

The combined capacity of all OECD nuclear power plants drops by a net 14 GW from 2015 to 2040. Among the OECD regions, only South Korea has a sizable (16 GW) increase in nuclear capacity. Capacity reductions in the United States, Canada, OECD Europe, and 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.

World delivered energy use by sector

Residential and commercial buildings

The buildings sector is made up of residential and commercial end users and presently 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 1.1%/year from 2015 to 2040. In non-OECD countries, residential energy use increases by an average of 1.7%/year from 2015 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 0.3%/year over the projection period. The lower growth rate in OECD countries results from relatively slow GDP and population growth, as well as improvements in building shells and in the efficiency of appliances and equipment.

In the commercial sector, energy consumption occurs in enterprises engaged in commercial-scale activity (often called the service sector). Globally, the IEO2017 Reference case projects average growth in commercial energy use of 1.2%/year from 2015 to 2040, with the highest rates of growth in non-OECD nations. Non-OECD commercial sector delivered energy use increases by 1.9%/year from 2015 to 2040. OECD commercial energy use expands by 0.7%/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 IEO2017 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, it is not the fastest-growing end-use sector, with growth in the buildings and transportation sectors outpacing industrial sector growth through 2040.

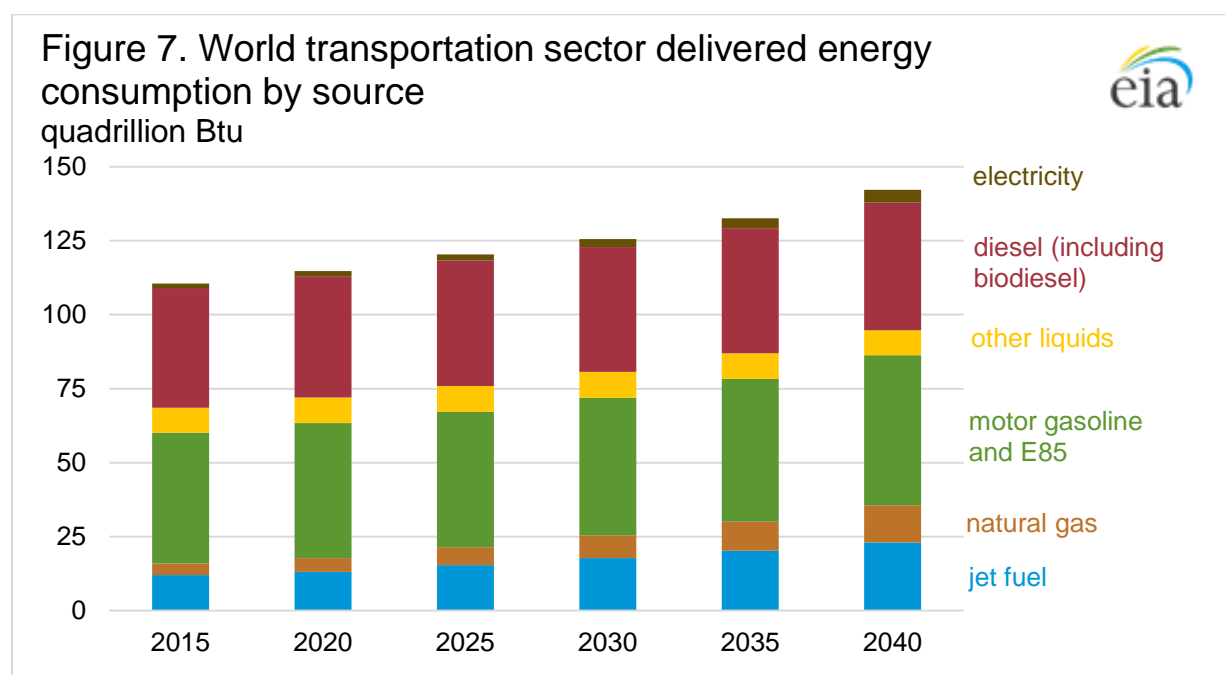
In the IEO2017 Reference case, worldwide industrial sector energy consumption is projected to increase by an average of 0.7%/year from 2015 to 2040. Most of the long-term growth occurs in non-OECD countries. From 2015 to 2040, industrial energy consumption in non-OECD countries grows by an average of 0.8%/year, compared with 0.2%/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 declines over the projection period, from 64% in 2015 to 58% in 2040. Many emerging non-OECD economies, especially China, move away from energy-intensive manufacturing, while energy use grows more rapidly 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 IEO2017 Reference case, delivered energy consumption in the world transportation sector increases at an annual average growth of 1.0%. All of the growth in

transportation energy use occurs in the developing, non-OECD economies from 2015 to 2040. 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. In OECD nations, where consuming patterns are already well established, relatively slower economic and population growth rates and strong vehicle efficiency improvements lead to a nearly 2% decrease in transportation energy use between 2015 and 2040.

Worldwide, liquid fuels remain the dominant source of transportation energy consumption, although its share of total transportation energy declines over the projection period, from 95% in 2015 to 88% in 2040. World liquid fuels used in the transportation sector grows by 20 quadrillion Btu, from 105 quadrillion Btu in 2015 to 125 quadrillion Btu in 2040. Jet fuel consumption shows the largest gain (11 quadrillion Btu), followed by motor gasoline—including ethanol blends (7 quadrillion Btu), and diesel (3 quadrillion Btu) (Figure 7). Motor gasoline remains the largest transportation fuel, but its share of total transportation energy consumption declines from 40% in 2015 to 36% in 2040.



Natural gas—driven by favorable economics in heavy trucking—and electricity—because of its use in passenger rail and light-duty vehicles—are expected to be the fastest-growing forms of transportation energy. The share of natural gas as a transportation fuel grows from 4% in 2015 to 9% in 2040. Natural gas consumption for passenger and freight transportation—excluding natural gas pipeline consumption—grows to nearly six times its 2015 level by 2040, reaching 9 quadrillion Btu in 2040. Electricity consumption in the transportation sector rises to more than 4 quadrillion Btu in 2040, when electricity accounts for 3% of global transport energy use.

World carbon dioxide emissions

World energy-related carbon dioxide (CO₂) emissions rise from 33.9 billion metric tons in 2015 to 36.4 billion metric tons in 2030 and to 39.3 billion metric tons in 2040 in the IEO2017 Reference case—an

increase of 16% over that period. Much of the growth in emissions is attributed to developing non-OECD nations, many of which continue to rely on fossil fuels to meet the growth in energy demand. In the IEO2017 Reference case, non-OECD emissions in 2040 total 26.9 billion metric tons, or about 25% higher than the 2015 level. In comparison, OECD emissions remain at about the same level of 12.4 billion metric tons throughout the projection period.

On November 4, 2016, the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement became effective, with signatory parties committing to take actions to keep the rise in the global temperature to less than 2 degrees Celsius above preindustrial levels when fully implemented [4]. Parties to the agreement were asked to submit their first nationally determined contributions (NDCs) that listed the actions they would take to achieve the Paris Agreement goals. NDCs can be adjusted if they are expected to be—in aggregate—insufficient to meet the agreed-upon 2-degree long-term goal. As of September 2017, 155 parties have submitted their NDCs to the UNFCCC [5].

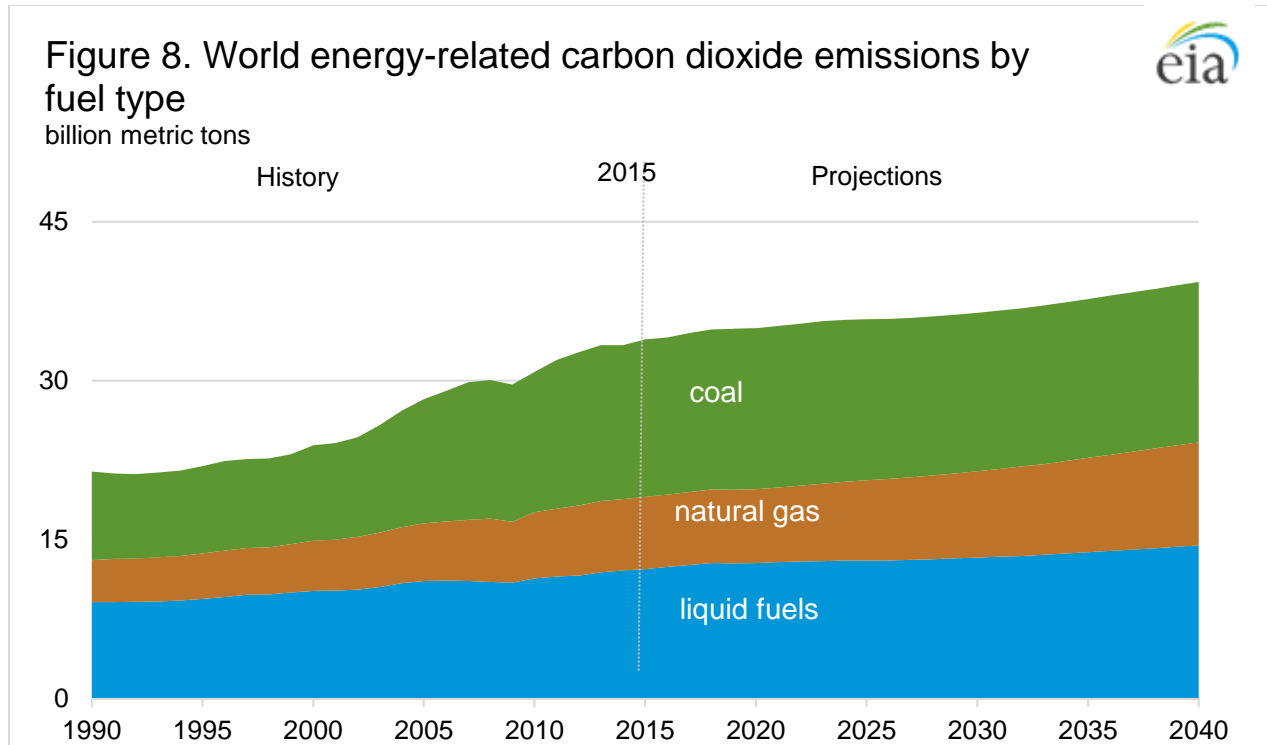
EIA tried to incorporate some specific details of the NDCs into the IEO2017 Reference case, such as renewable energy and other lower-emitting generation mix goals. However, a great deal of uncertainty remains about the full implementation of policies to meet the stated goals, because most commitments have been made only through 2030, and it is uncertain how they will ultimately achieve these goals. In addition, beyond energy-related CO₂, other gases (e.g., methane) and sources (e.g., deforestation) that contribute to net greenhouse gas (GHG) emissions but are not considered in IEO2017 projections could have significant effects on national or regional shares of total GHG emissions and the achievement of NDCs. In the future, 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.

On June 1, 2017, the United States announced that it would withdraw from the Paris Agreement. However, the primary mechanism for U.S. participation is the Clean Power Plan (CPP), which is still in place, but currently being challenged in court. Even with the CPP, the United States does not meet its NDC targets based on reductions projected from compliance with the CPP alone in the Reference case.

World energy-related CO₂ emissions from the use of liquid fuels and natural gas increase in the IEO2017 Reference case, while coal-related emissions remain largely flat through 2040 (Figure 8). CO₂ emissions related to the combustion of liquids grow at an annual rate of 0.7% from 2015 to 2040. With the exception of some penetration of electric- and natural gas-powered vehicles, no ready substitutes are available for liquids in the transportation sector, which drives up the demand for liquids. By 2040, the global emissions from liquid fuels are almost the same as those from coal. CO₂ emissions from natural gas rises by 1.4%/year from 2015 to 2040, as natural gas increasingly displaces coal for electricity generation.

⁴See "The Paris Agreement," http://unfccc.int/paris_agreement/items/9485.php.

⁵See "NDC Registry (interim)," <http://www4.unfccc.int/ndcregistry/Pages/Home.aspx>



Worldwide coal-related CO₂ emissions are relatively stable throughout the projection, increasing by only 0.1%/year from 2015 to 2040, or 260 million metric tons. Coal consumption in China and the United States—currently two of the world’s largest coal-consuming nations—drops substantially in the Reference case, with coal-related CO₂ emissions declining by 1,166 million metric tons in China and by 478 million metric tons in the United States. However, coal use in India and other developing nations continues to increase, offsetting the decreases in coal-related CO₂ emissions that occur elsewhere.