

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)

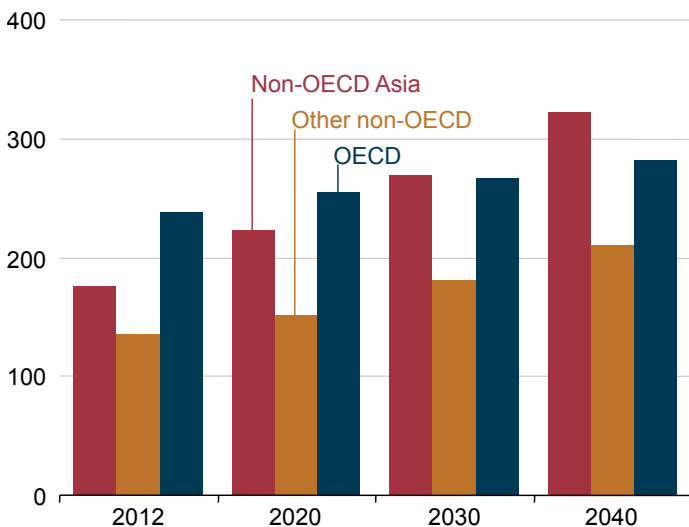
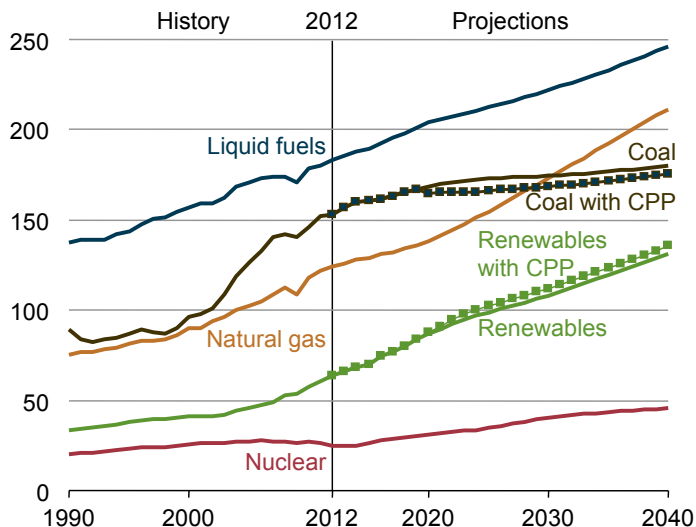


Figure ES-2. Total world energy consumption by energy source, 1990–2040 (quadrillion Btu)



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

³For 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 CPP⁴ 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.

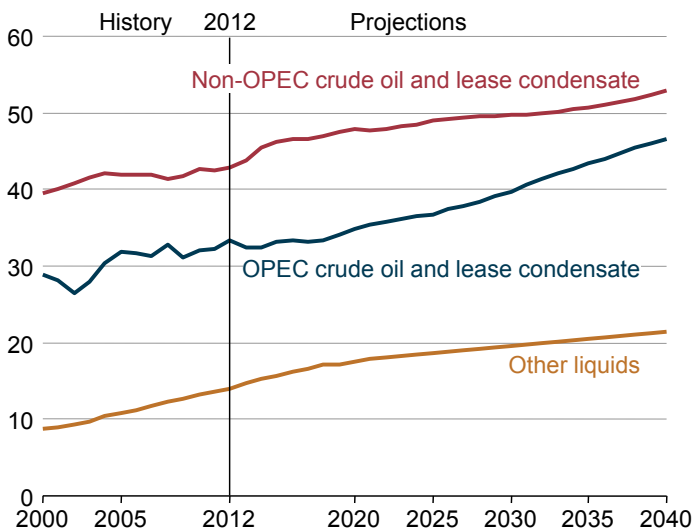
Liquid fuels

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 condensate⁵ 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

⁴U.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/>.

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

⁶Other liquid fuels include natural gas plant liquids (NGPL), biofuels, gas-to-liquids (GTL), coal-to-liquids (CTL), kerosene, 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)

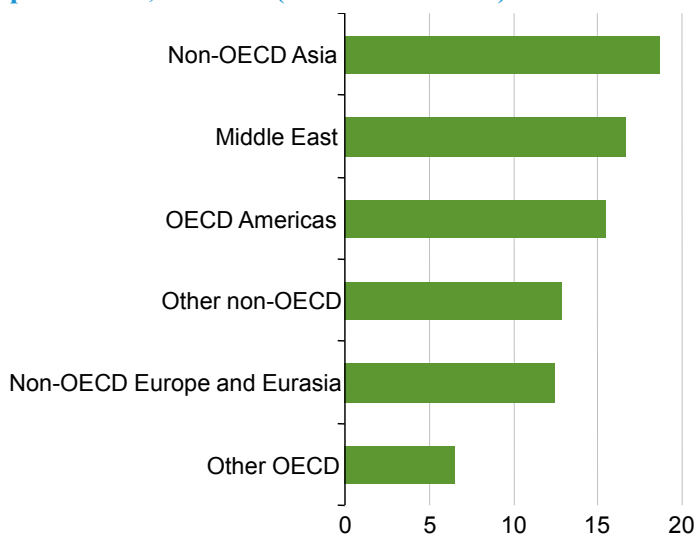
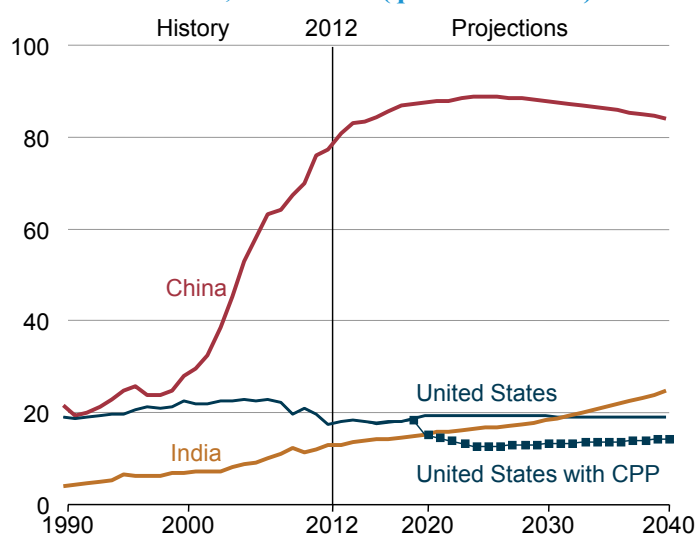


Figure ES-5. Coal consumption in China, India, and the United States, 1990–2040 (quadrillion Btu)



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

⁷U.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

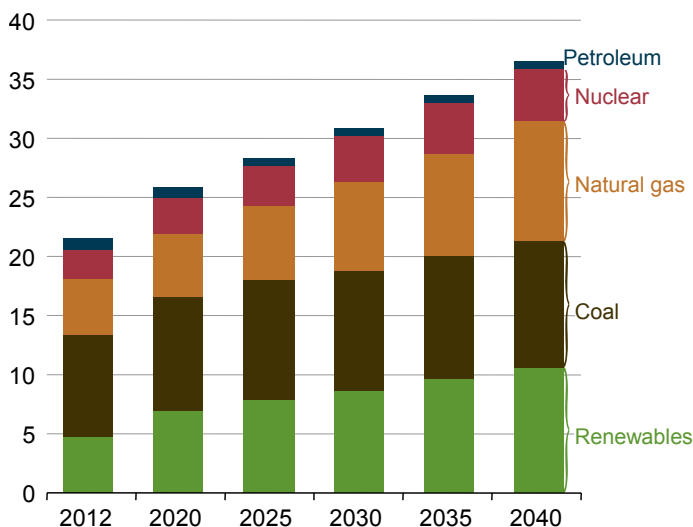
It is important to examine patterns in the consumption of energy delivered to end users to fully assess future global energy use. This section discusses delivered energy consumption in the buildings, industrial, and transportation sectors. Energy losses associated with electricity generation and transmission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

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

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



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

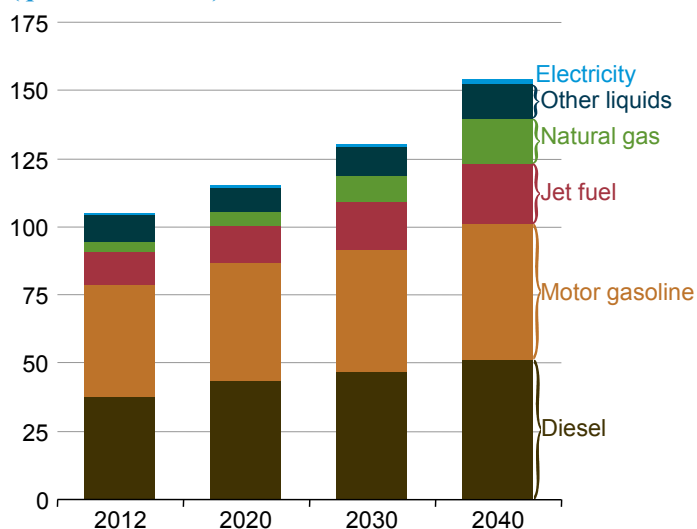
Energy use in the transportation sector includes the energy consumed in moving people and goods by road, rail, air, water, and pipeline. In the IEO2016 Reference case, world delivered energy consumption in the transportation sector increases at an annual average rate of 1.4%. Virtually all (94%) of the 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)

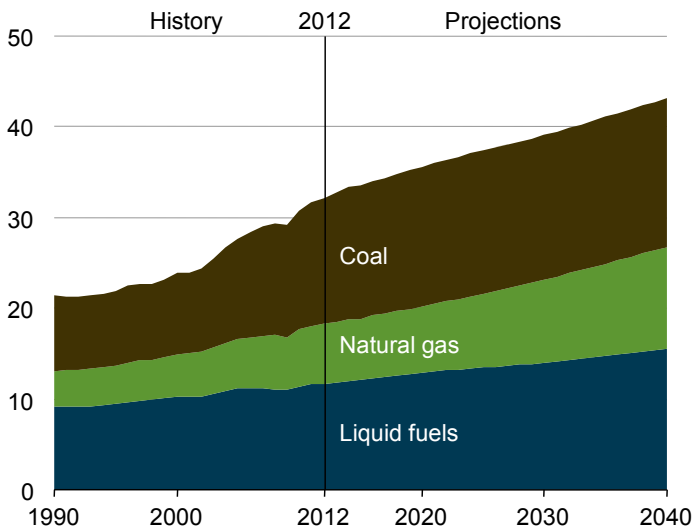


World carbon dioxide emissions

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.

⁸U.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/>.