

Chapter 1

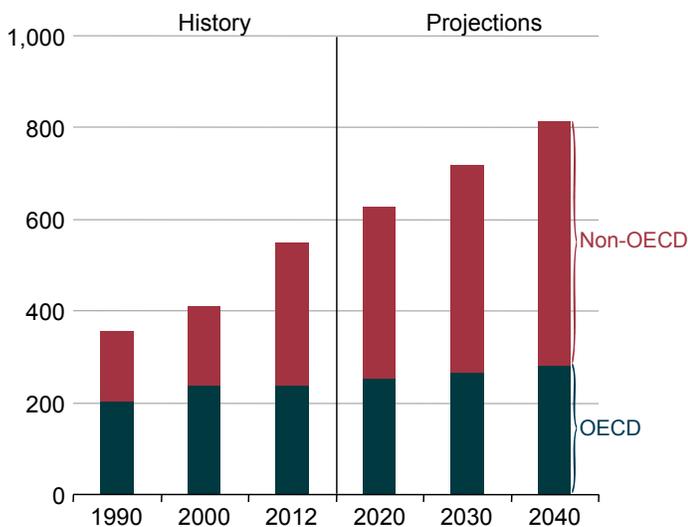
World energy demand and economic outlook

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 CPP⁹ 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 or IEO2016 Reference cases. However, the impact is addressed (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 |

⁹U.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/>.

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 146 quadrillion Btu) from 2012 to 2040. China and India, in particular, have been among the world’s fastest-growing economies

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

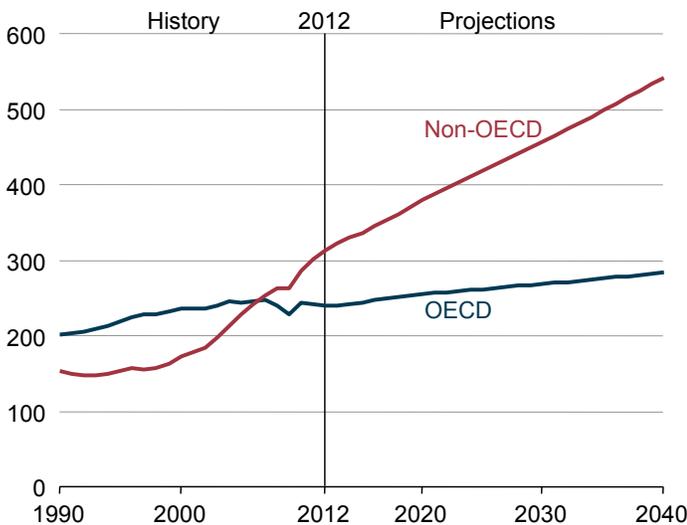
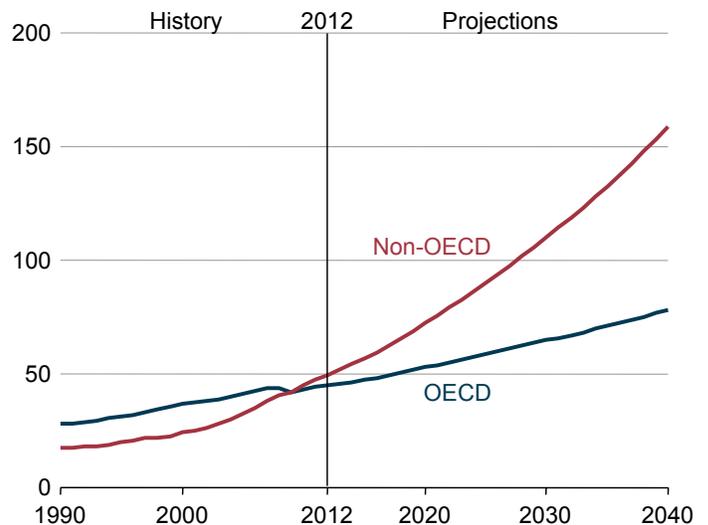


Figure 1-3. World total gross domestic product, 1990–2040 (trillion 2010 dollars)



¹⁰For 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.

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)

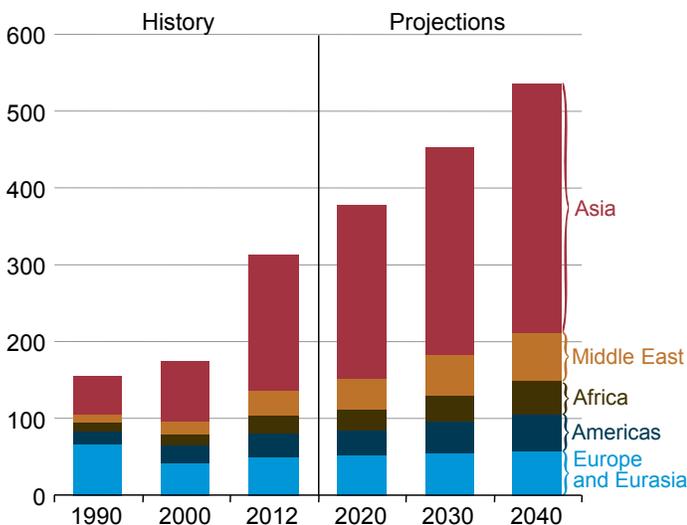
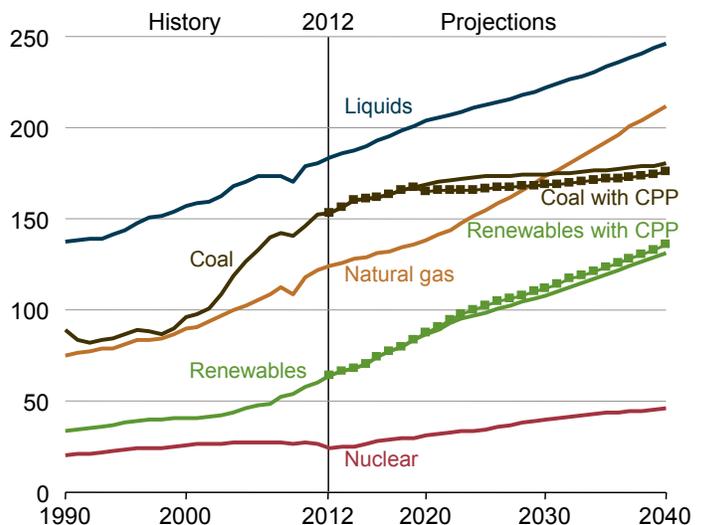


Figure 1-5. World energy consumption by energy source, 1990–2040 (quadrillion Btu)



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.

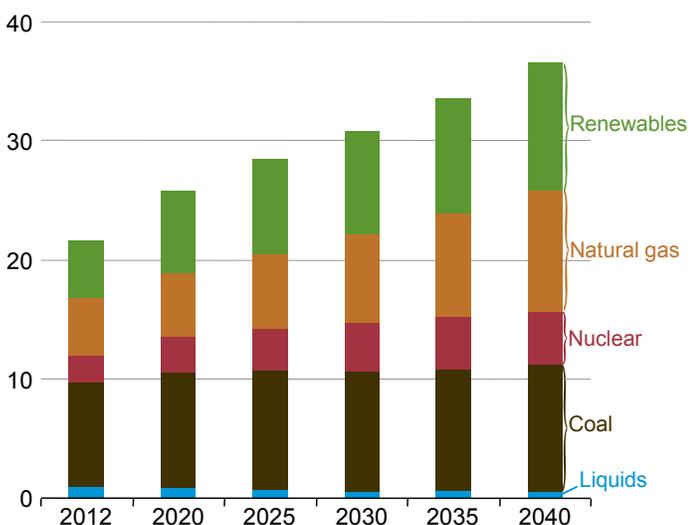
Coal, which currently provides the largest share of energy for world electricity generation in the IEO2016 Reference case (Figure 1-6), declines from 40% of total generation in 2012 to 29% in 2040.¹³ In addition, if the U.S. CPP were included in the projections, the coal share of world generation would 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.

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-

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



¹¹U.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%.

¹²U.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/>.

¹³This 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 users¹⁴ 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)

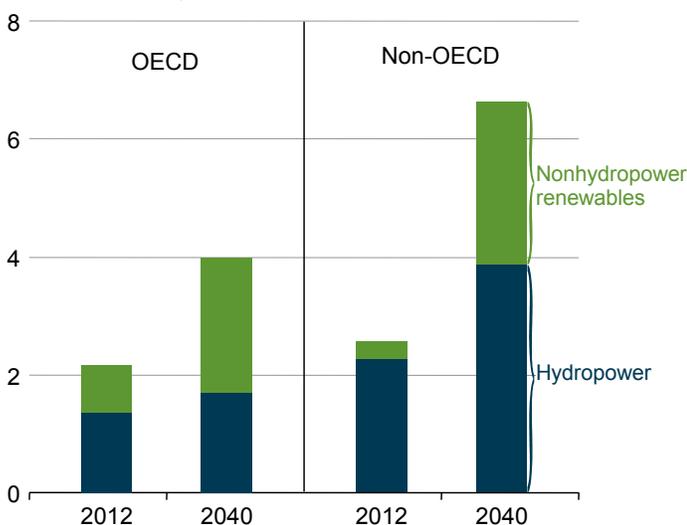
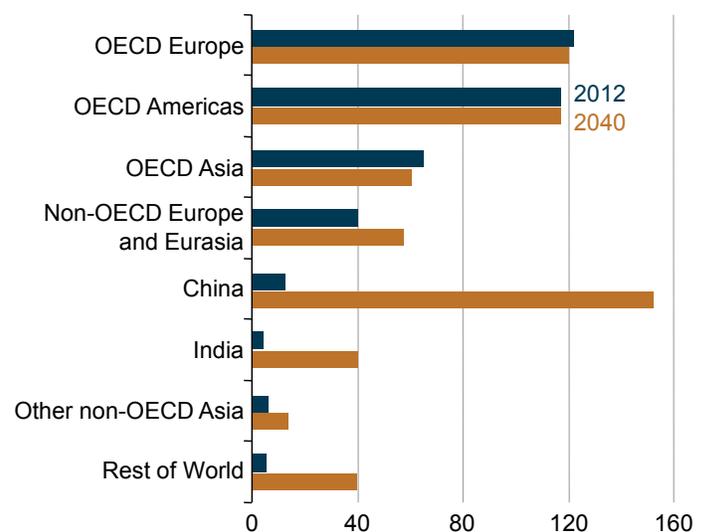


Figure 1-8. World nuclear electricity generation capacity by region, 2012 and 2040 (gigawatts)



¹⁴Delivered 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.

¹⁵Backtesting 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 2040¹⁶ (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.

¹⁶The 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.

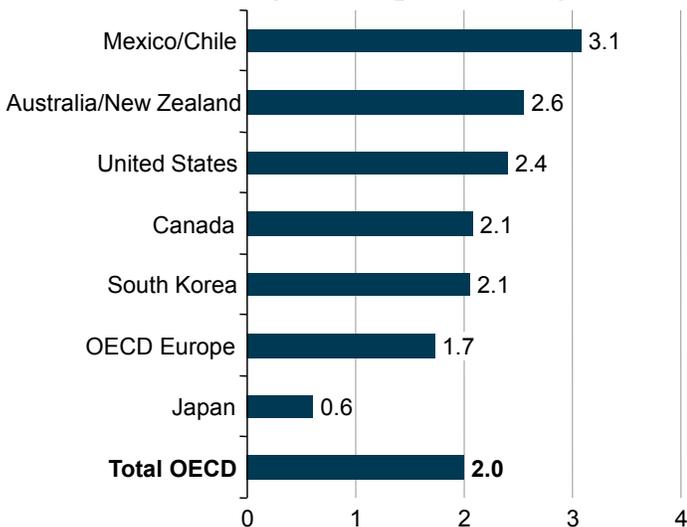
Canada's economic growth in the Reference case, at 2.1%/year from 2012 to 2040, is slower than that of the United States. Although recent declines in oil prices reduce Canadian GDP growth in the near term, prospects for the long term are relatively healthy, given Canada's record of fiscal prudence and 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

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



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.

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 |

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

¹⁸Federal 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.

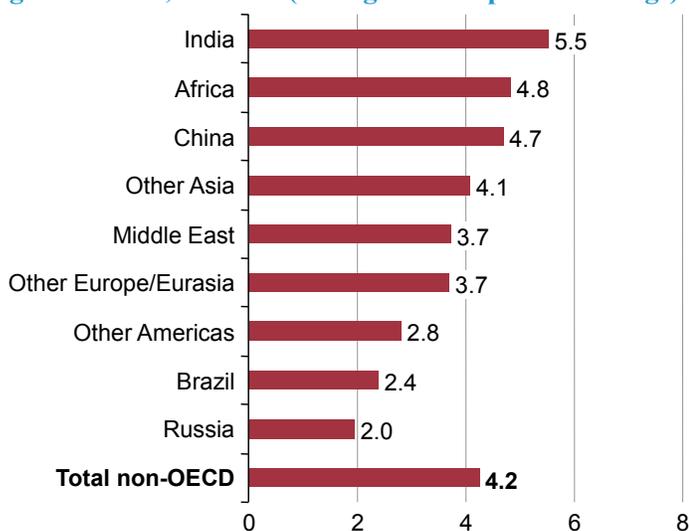
China's economic growth in 2014 was its lowest in 24 years, and it continues to slow in the IEO2016 Reference case with an average growth rate of 4.7%/year from 2012 to 2040. The slower economic growth is in part the result of demographics—China has an aging population and shrinking work force—accompanied 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

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



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.

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

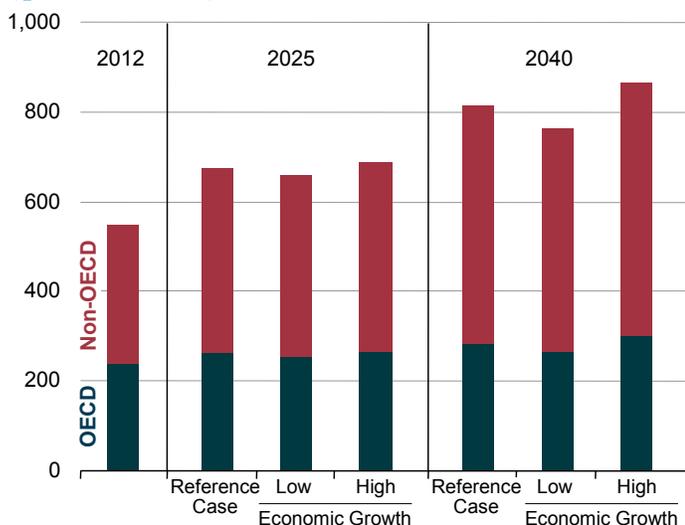
Expectations for future rates of economic growth are a major source of uncertainty in the IEO2016 projections. To illustrate the uncertainties associated with economic growth trends, IEO2016 includes a High Economic Growth case and a Low Economic Growth case in addition to the Reference case. The two 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.

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.

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



¹⁹IHS 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.

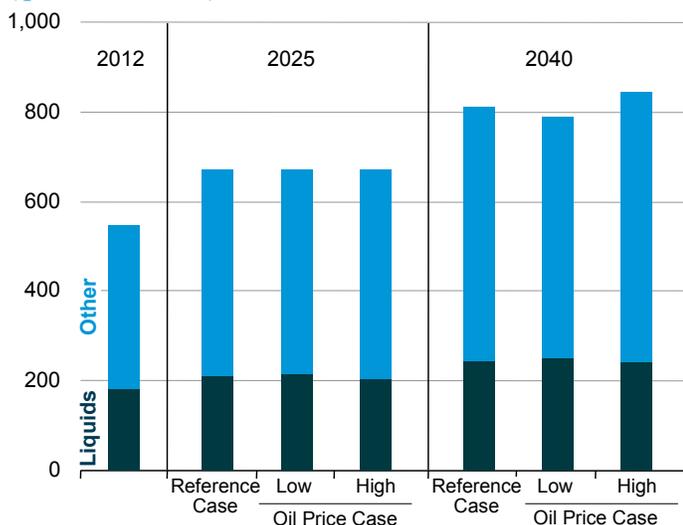
In the Low Oil Price case, crude oil prices are \$76 per barrel (2013 dollars) in 2040. GDP growth in the non-OECD countries averages 3.9%/year from 2012 to 2040, compared with Reference case growth of 4.2%/year. A combination of lower economic activity and lower prices results in a level of non-OECD 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

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



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.

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.