ExxonMobil

2018 Outlook for Energy: A View to 2040

2018 Outlook for Energy:

A View to 2040

The *Outlook for Energy* is ExxonMobil's view of energy demand and supply through 2040. We use the *Outlook* to help inform our long-term business strategies and investment plans.

A significant energy transition is underway, and many factors will shape the world's energy future. These include government ambitions and policies that seek to promote prosperity while also addressing the risks of climate change. The recent Paris Agreement[1] on climate change provided significant insights on governments' intentions to reduce greenhouse gas (GHG) emissions through the inclusion in the agreement of nationally determined contributions (NDCs). Policies adopted to support NDCs will likely affect supply and use of energy across society.

To support economic progress and make substantial progress on the climate goals identified in the Paris Agreement, well-designed and transparent policy approaches that carefully weigh costs and benefits are needed. Such policies are likely to help manage the risks of climate change while also enabling societies to pursue other high-priority goals – including clean air and water, access to reliable, affordable energy and economic progress for all people.

Technology will also be vital to improve living standards while addressing climate risks. Advances continue to reshape the energy playing field. Many technologies not prevalent five to 10 years ago have a more significant role today, and their impacts will continue to expand. Examples include wind and solar power, unconventional oil and gas development, and electric cars. Meeting the dual challenge of mitigating the risks of climate change while boosting standards of living will require additional technology advances.

While policies and technologies help shape living standards and the evolution of energy, they also disrupt the status quo and can cause uncertainty and unexpected consequences. Accordingly, as part of the *Outlook* development process, we develop and use sensitivities to help our understanding of possible energy outcomes.

This year's *Outlook* includes several sensitivities on specific areas of interest to provide greater perspective on how changes to our base *Outlook* assumptions could affect the energy landscape.

This year's *Outlook* also includes a new section, "Pursuing a 2°C Pathway." This section utilizes work coordinated by the Energy Modeling Forum at Stanford University.[2] It provides a view of potential pathways toward a 2°C climate goal, and the implications such pathways might have in terms of global energy intensity, carbon intensity of the world's energy mix and global demand for various energy sources. The section concludes with a discussion of the need to pursue practical, cost-effective solutions to address multiple goals simultaneously.

The *Outlook* anticipates significant changes through 2040 across the world to boost living standards, reshape the use of energy, broaden access to abundant energy supplies, and accelerate decarbonization of the world's energy system to address the risks of climate change.

A role for everyone

Seven billion people shape the world's energy system and have a direct impact on the fundamental drivers of energy demand. Energy impacts the economy as well as security and environmental goals. Energy solutions can vary over time and circumstances. Think about how access to energy affects your own life, and how that translates to billions of other people around the world. Compare your own conclusions on the energy future with those in the *Outlook*.

Energy is fundamental to modern life, and as the world's population approaches 9 billion people in 2040, we are challenged to improve living standards everywhere. We expect that progress will be powered by human ingenuity and the energy that helps make better lives possible.

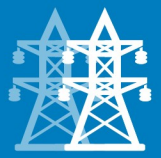
Key takeaways

At a glance

Key trends that will play a defining role in our global energy landscape through 2040.

Energy powers modern economies and living standards
By 2030, the world's economic middle class will likely expand from 3 billion to more than 5 billion people. This growth will coincide with vastly improved living standards, resulting in rising energy use in many developing countries as people develop modern businesses and gain access to cars, appliances and air-conditioned homes.

Global energy needs rise about 25%, led by non-OECD nations
Despite efficiency gains, global energy demand will likely increase nearly 25 percent. Nearly all growth will be in non-OECD countries (e.g. China, India), where demand will likely increase about 40 percent, or about the same amount of energy used in the Americas today.

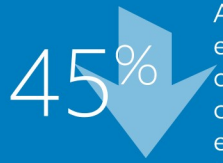


Electricity demand nearly doubles in non-OECD nations
Human activity continues to be dependent on reliable supplies of electricity. Global electricity demand will rise by 60 percent between 2016 and 2040, led by a near doubling of power demand in non-OECD countries.

Electricity from solar and wind increases about 400%
Among the most rapidly expanding energy supplies will be electricity from solar and wind, together growing about 400 percent. The combined share of solar and wind to global electricity supplies is likely to triple by 2040, helping the CO_2 intensity of delivered electricity to fall more than 30 percent.

Natural gas expands role to meet a wide variety of needs
The abundance and versatility of natural gas make it a valuable energy source to meet a wide variety of needs while also helping the world shift to less carbon-intensive sources of energy. Natural gas use is likely to increase more than any other energy source, with about half its growth for electricity generation.

Oil plays a leading role to aid mobility and modern products
More electric cars and efficiency improvements in conventional engines will likely lead to a peak in liquid fuels use by the world's light-duty vehicle fleet by 2030. However, oil will continue to play a leading role in the world's energy mix, with growing demand driven by commercial transportation and the chemical industry.



Decarbonization of the world's energy system will accelerate
As the world's economy nearly doubles by 2040, energy efficiency gains and a shift to less carbon-intensive sources of energy will contribute to a nearly 45 percent decline in the carbon intensity of global GDP. Global energy-related CO_2 emissions will likely peak by 2040 at about 10 percent above the 2016 level.

2018 Outlook for Energy

Contents

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Energy lives here™

Behind the scenes

How we forecast to 2040

ExxonMobil uses a data-driven, bottom-up approach to produce a most-likely view of future energy demand and supply.

Foundation

We create a starting point for our projections using International Energy Agency (IEA) annual data, along with third-party data and recent energy trends.

Economic growth

Since population and living standards drive energy demand, we forecast demographic and economic trends for about 100 regions covering the world.

Demand for services

These drivers, along with consumer preferences, help us determine demand for energy across 15 sectors, covering needs for personal mobility, electricity in buildings, production of steel, cement and chemicals, plus many others.

Energy sources

We then match the demand for energy services with about 20 types of energy (e.g., diesel), taking into account potential evolution of technology, policies, infrastructure and more.

Policy/tech changes

We actively monitor changes in technology and policies and compare our views of the *Outlook* to a variety of third-party estimates.

Test uncertainty

We also run sensitivities (i.e., changes to our base assumptions) to assess the impact on our forecast if things were to play out differently.

2018 Outlook for Energy

Fundamentals

What will the world's energy picture look like in the future?

To answer this question, we need to start by analyzing the world's long-term demographic and economic trends.

By 2040, world population is expected to reach 9.2 billion people, up from 7.4 billion today. Over that same period, global GDP will likely double. As a result, per capita GDP is projected to rise significantly, particularly in the non-member countries of the Organisation for Economic Co-operation and Development (OECD). Billions of people are expected to join the global middle class.

Rising living standards for expanding populations worldwide mean a dependence on reliable modern energy. Combined, they are expected to help drive up global energy demand by about 25 percent by the year 2040. That is roughly equivalent to adding another North America and Latin America to the world's current energy demand.

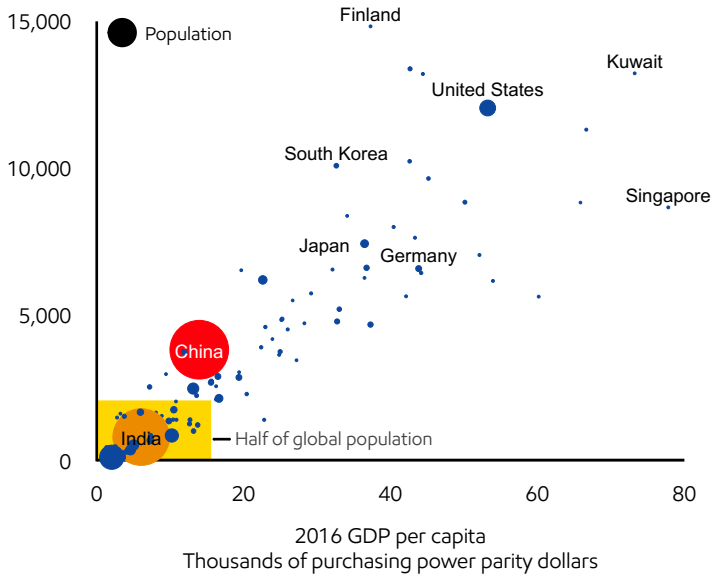
The world will need to pursue all economic energy sources to keep up with this considerable demand growth.

Fundamentals

Global fundamentals – projections

Energy supports living standards

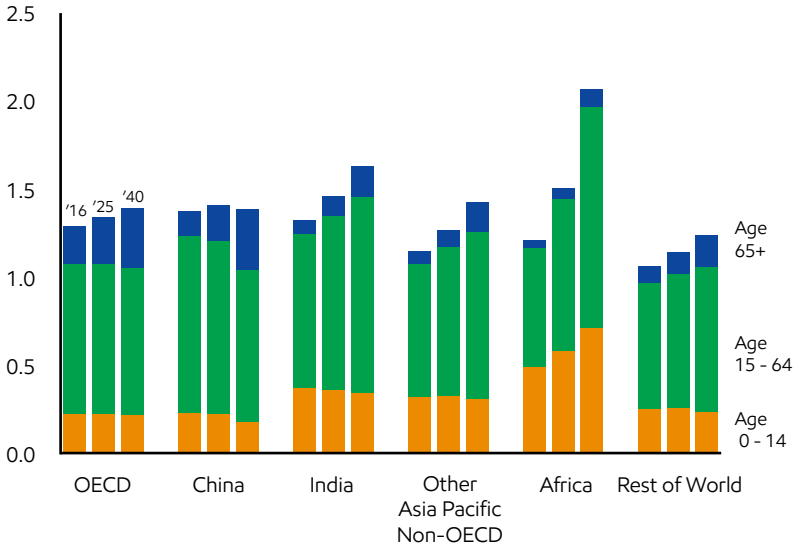
2016 Electricity demand per capita
Kilowatt-hour (kWh) per person



- Energy plays a critical role in supporting rising modern living standards around the world
- Electricity use per capita is one important measure of energy consumption
- A country's electricity use per capita is well-aligned with its income level
- About half of the global population resides in countries where average electricity demand per person is less than the annual consumption of basic household appliances
- About 1 billion people still lack access to electricity

World demographics continue to shift

Billions of people



Source: World Bank, ExxonMobil estimates

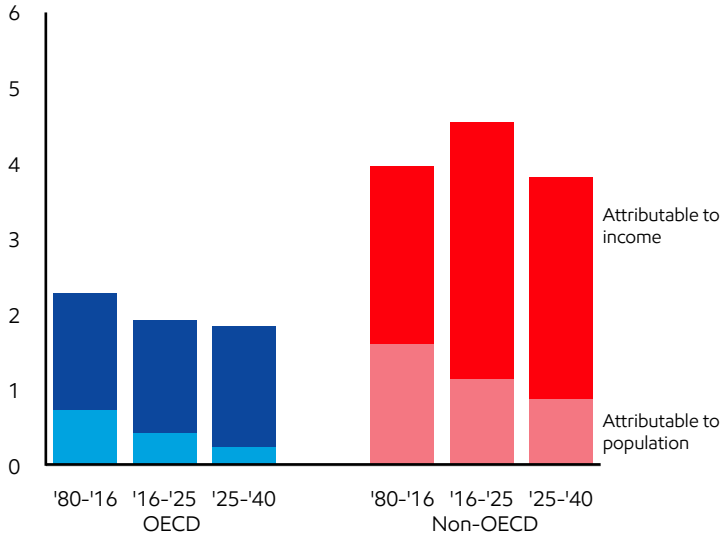
- Global population grows from 7.4 billion today to 9.2 billion people in 2040
- Africa's population increases at the fastest rate across major regions; it also has the largest working-age population across regions by 2040
- India likely to replace China as the most populous nation by 2025, with a significant increase in working-age population
- China's population will gradually trend down post 2030; its working-age population has already peaked, and its share of population age 65+ increases rapidly
- OECD working-age population flattens while the 65+ group continues to grow

Fundamentals

Global fundamentals – projections

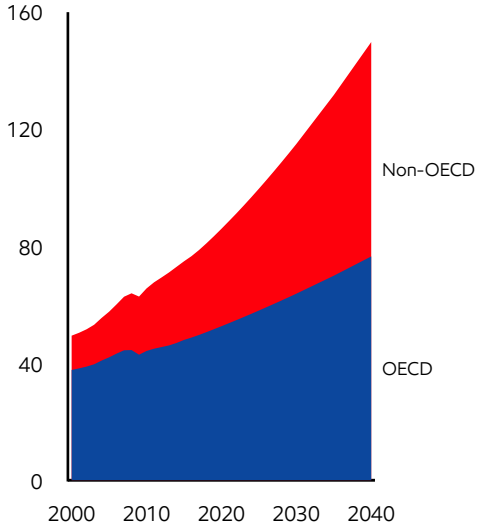
Non-OECD leads economic expansion

GDP growth
Year-over-year average percent (%)



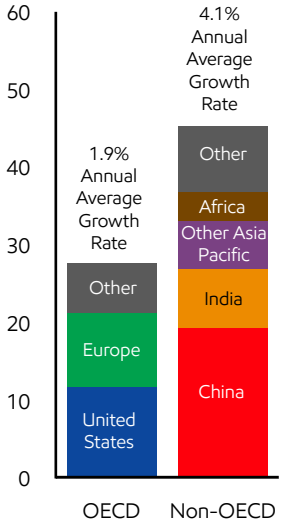
World GDP doubles

Trillions of 2010 dollars



World GDP growth

Trillions of 2010 dollars



- Economic output (GDP) growth consists of both income (measured by GDP per capita) and population growth
- Projected OECD GDP growth trend reflects declining population growth and steady rise of income
- Non-OECD GDP growth to 2025 expected to rise above historical average, reflecting higher income growth and slower population growth
- Non-OECD GDP growth post-2025 projected to moderate as population growth slows further, while income growth is largely maintained

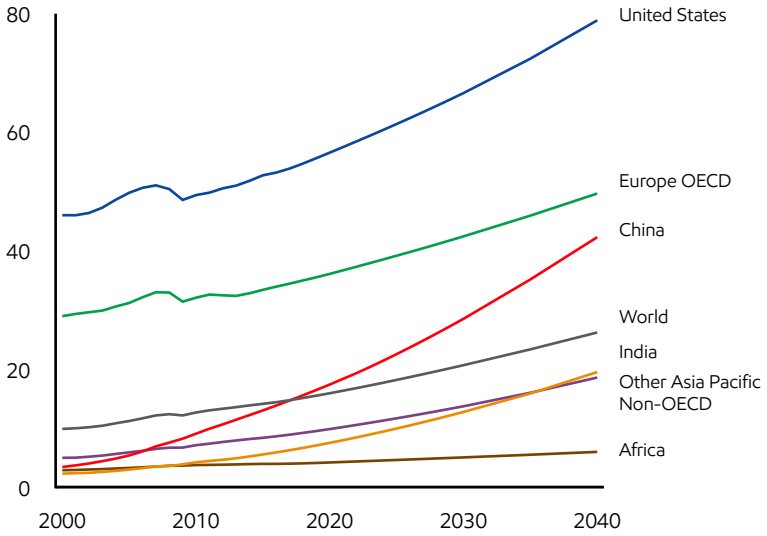
- World GDP likely to double from 2016 to 2040, with non-OECD GDP increasing about 165 percent, and OECD GDP growing about 60 percent
- Non-OECD share of global GDP will rise to about 50 percent by 2040, up from about 35 percent in 2016
- China is likely to be the largest contributor to GDP gains, with growth similar to that of Europe OECD and the United States combined
- India will grow strongly, with its share of global GDP doubling

Fundamentals

Global fundamentals – projections

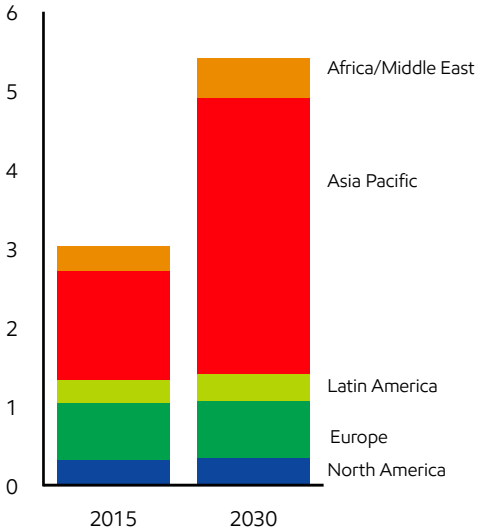
Purchasing power expands

GDP per capita – thousands of purchasing power parity dollars



Unprecedented middle-class growth

Global middle class – billions of people



Source: The Brookings Institution

- All regions show significant gains in income by 2040
- GDP per capita in OECD nations currently averages about four times that of non-OECD economies
- China GDP per capita is likely to triple to more than $40,000 by 2040, similar to Europe OECD levels of purchasing power in 2030
- India GDP per capita is also expected to triple, but will be less than half of China's level by 2040
- Africa GDP per capita is expected to increase by 50 percent, still trailing other emerging markets significantly

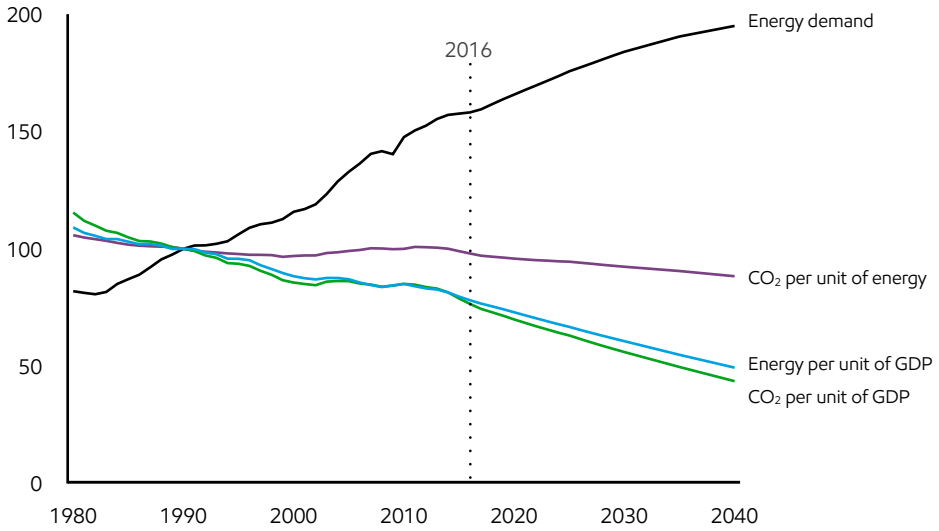
- Middle class to expand globally, growing about 80 percent by 2030 to reach more than 5 billion people; most of the growth comes from non-OECD countries
- The rising middle class means billions of people with longer, healthier and better lives
- Asia Pacific represents the largest increase, with India and China each reaching more than 1 billion middle-class citizens
- Africa/Middle East and Latin America are also expected to increase, while North America and Europe hold their middle-class population steady

Fundamentals

Global fundamentals – projections

Technology helps us do more with less

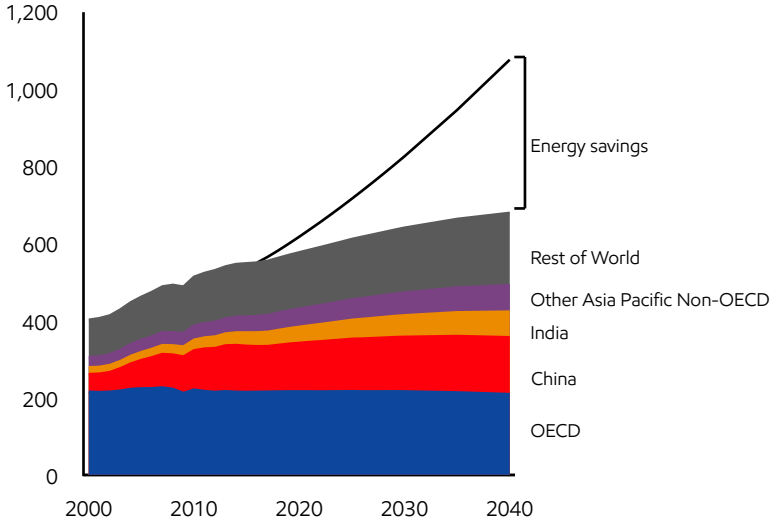
Index, 1990=100



- Global energy demand grows more slowly than world GDP, implying falling energy intensity (amount of energy used to produce a unit of GDP)
- From 2000 to 2016, energy intensity declined about 1 percent per year, the rate of improvement from 2016 to 2040 is likely to approach 2 percent per year
- Meanwhile, the carbon intensity of energy (CO_2 content per unit of energy used) has been fairly flat; the pace of improvement is likely to pick up from 2016 to 2040
- The combined effect is reflected in decreasing carbon intensity of the world economy (tonnes CO_2 per unit of GDP), which is expected to be nearly 45 percent lower by 2040 as global energy demand rises about 25 percent

Global efficiency limits demand growth

Energy demand – quadrillion British thermal units (BTUs)



- Despite growing population, global energy demand is expected to increase about 25 percent from 2016 to 2040, reflecting large savings due to efficiency improvements
- Without energy savings enabled by gains in energy efficiency of the world's economy global energy demand could nearly double by 2040
- Demand growth will come from non-OECD nations, led by China and India, where energy use is expected to rise about 40 percent
- Demand in other Asia Pacific nations, Africa/Middle East and Latin America is similarly projected to grow strongly

2018 Outlook for Energy

Demand

Global energy demand will continue to rise through 2040, reflecting its fundamental link to growing prosperity and better living standards for an increasing population worldwide.

Energy efficiency improvements will help curb the growth in global energy demand to about 25 percent over the period to 2040, while global economic output nearly doubles. To put this in perspective, if world energy demand grew as fast as estimated GDP, energy demand growth could be about four times the projected amount.

Emerging markets in non-OECD nations will account for essentially all energy demand growth, led by the expanding economies in the Asia Pacific region.

Continuing urbanization and a significant expansion of the middle class, particularly in China and India, will help drive this trend, highlighted by greater access to modern energy in homes, rising industrial demand, and significant increases in personal and commercial transportation needs.

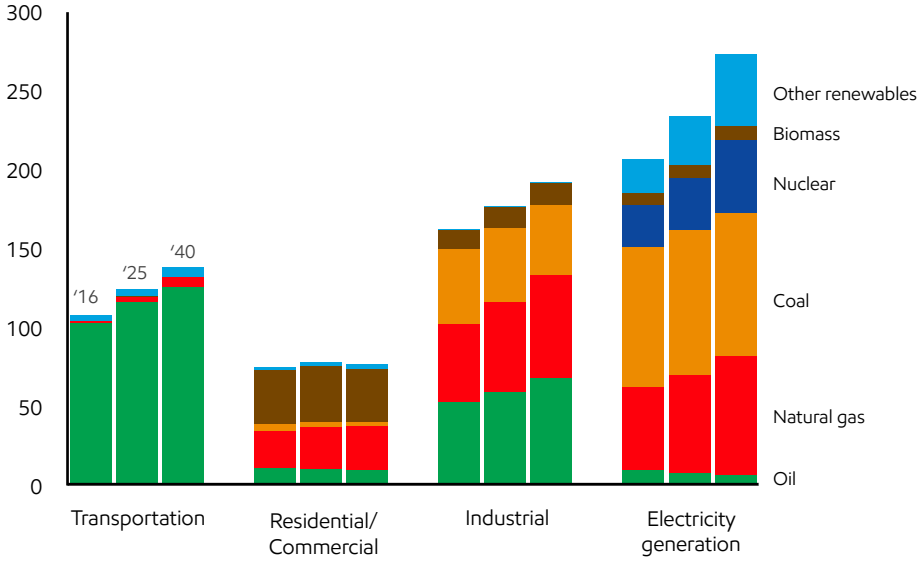
Electrification and gradual decarbonization continue as significant global trends. Energy demand for power generation accounts for about 50 percent of global demand growth. Energy sources shift toward cleaner fuels such as natural gas, renewables and nuclear.

Demand

Demand – projections

Global energy demand varies by sector

Primary energy* [3] – quadrillion BTUs

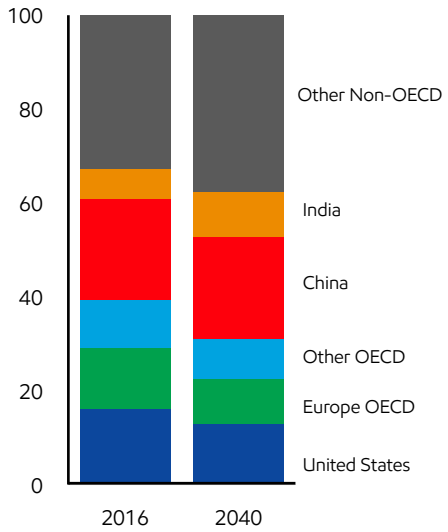


*Includes consumed energy as fuel and feedstocks

- Energy used in each sector reflects economic supply options and their general fitness for purpose
- Electricity generation is the largest and fastest-growing demand sector, reflecting strong growth in global electricity demand
- A wide variety of energy types will support electricity generation, with natural gas, renewables and nuclear increasing their share
- Natural gas demand increases significantly and gains share in all sectors
- Oil demand grows to support commercial transportation and chemical needs

Energy demand shifts toward non-OECD

Percent of primary energy (%)



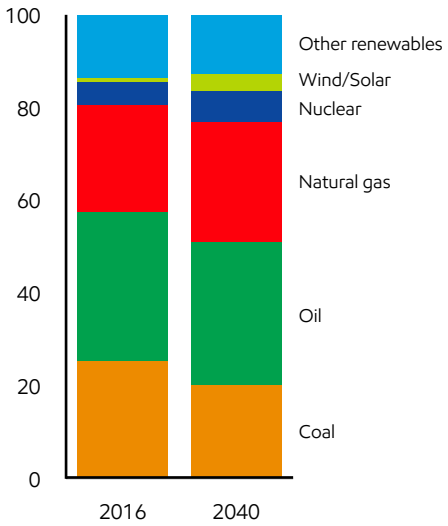
- Global demand reaches 680 quadrillion British thermal units in 2040, up nearly 25 percent
- Non-OECD share of global energy demand reaches about 70 percent in 2040, as efficiency gains and slowing economic growth in the United States and OECD nations help keep energy demand relatively flat
- China and India contribute about 45 percent of world energy demand growth
- The combined share of energy used in the United States and in European OECD nations will decline from about 30 percent in 2016 to close to 20 percent in 2040, similar to China's share of world energy demand

Demand

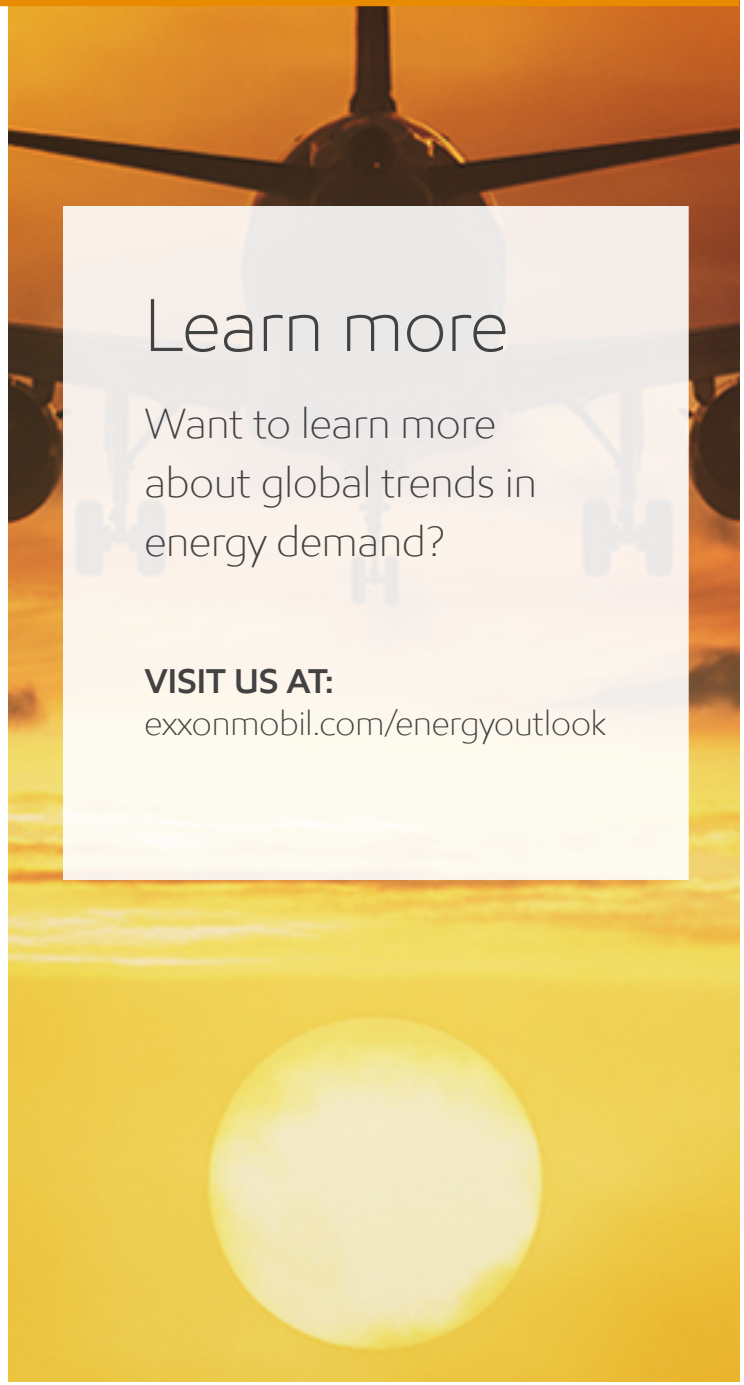
Demand – projections

Global energy mix shifts to lower-carbon fuels

Percent of primary energy (%)



- Renewables and nuclear see strong growth, contributing close to 40 percent of incremental energy supplies to meet demand growth
- Natural gas grows the most of any energy type, reaching a quarter of all demand
- Oil will continue to play a leading role in the world's energy mix, with growing demand driven by commercial transportation needs and feedstock requirements for the chemicals industry
- Coal use remains significant in parts of the world, but loses substantial share as the world transitions toward energy sources with lower emissions



Learn more

Want to learn more about global trends in energy demand?

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Transportation

Advancements in transportation have shrunk our world, while opening up new vistas and possibilities. One consequence of billions of people joining the global middle class in the next quarter century is that it will lead to greater travel, additional cars on the road and increased commercial activity.

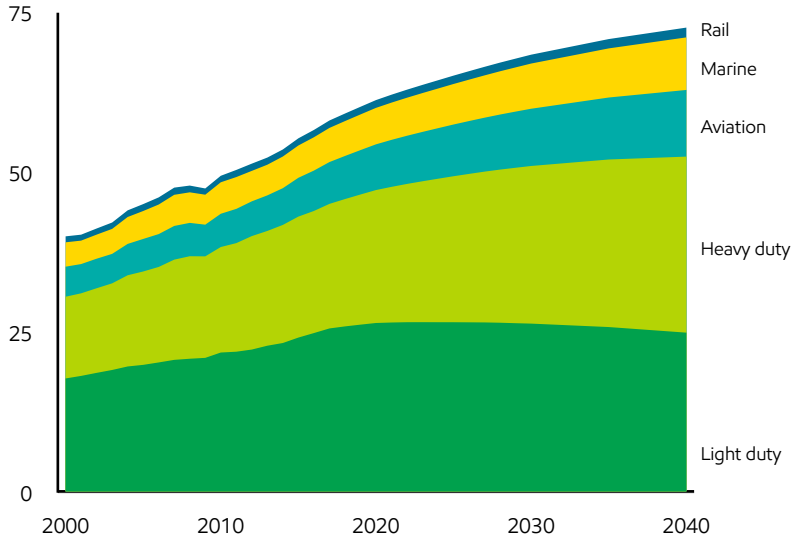
Global transportation-related energy demand is projected to increase by close to 30 percent. At the same time, total miles traveled per year by cars, sport utility vehicles (SUVs) and light trucks will increase about 60 percent, reaching about 14 trillion in 2040. As personal mobility increases, average new-car fuel economy (including SUVs and light trucks) will improve as well, rising from about 30 miles per gallon now to close to 50 miles per gallon in 2040.

The growth in transportation energy demand is expected to account for about 60 percent of the growth in liquids fuel demand. Liquids demand for light-duty vehicles is expected to be relatively flat to 2040, reflecting better fleet fuel economy and significant growth in electric cars.

Transportation – projections

Transportation energy demand growth driven by commerce

Global sector demand – million oil-equivalent barrels per day (MBDOE)



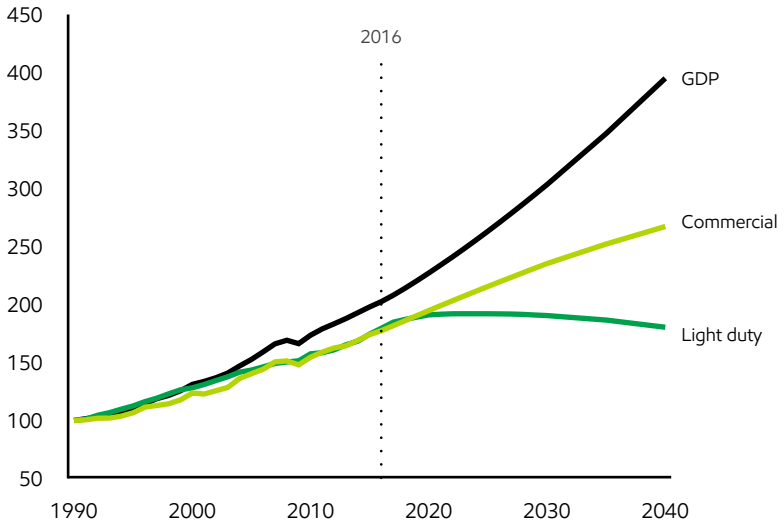
- Global transportation-related energy demand grows close to 30 percent from 2016 to 2040
- Personal mobility demands continue to increase, but higher efficiency and more electric vehicles lead to a peak and decline in light-duty vehicle energy demand
- Growth in economic activity and personal income drives increasing trade of goods and services, leading to higher energy demand in the commercial transportation sector
- Heavy-duty vehicle growth is the largest sector by volume, but aviation grows the largest by percentage

Demand

Transportation – projections

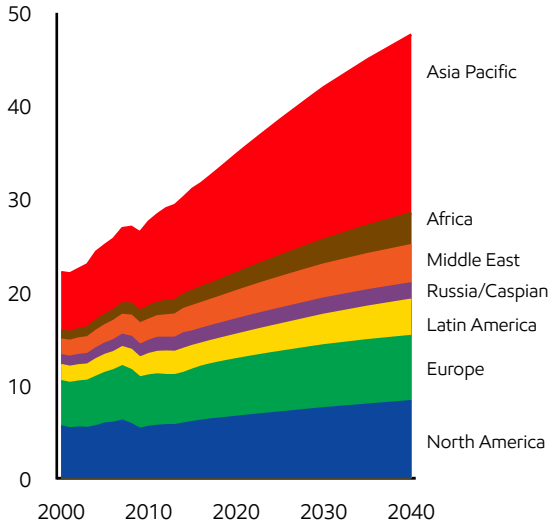
Global transportation energy demand relative to GDP

Index, 1990=100



Commercial transportation grows in all aspects

Commercial transportation energy demand – MBDOE



- Growth in personal mobility (vehicle miles traveled) and commercial transportation services (ton-miles of freight, passenger-miles of air travel) has tracked with GDP
- Continued economic growth, particularly in non-OECD countries, will result in increased demand for all transportation services
- Recent trends show a decoupling of economic growth and transportation energy demand, reflecting growing efficiency
- Significant increases in future fuel economy across all transportation modes will lead to a further decoupling of transportation services and energy demand

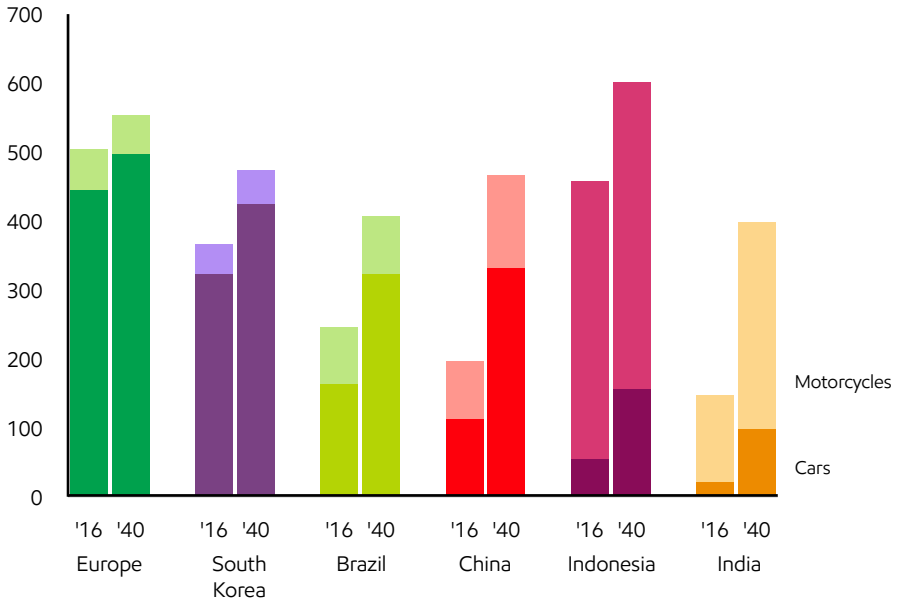
- Economic and population growth is concentrated in non-OECD countries, which leads to the biggest growth in commercial transportation services in these regions
- Asia Pacific leads growth, rising to 40 percent of total sector's energy demand
- Efficiency gains resulting from improvements in fuels, engine design, aerodynamics, body design and logistics across commercial modes of travel lead to significant reductions in the rate of energy demand growth
- Electrification in most commercial transportation grows slowly due to upfront costs, range limitations, payload requirements, and infrastructure development

Demand

Transportation – projections

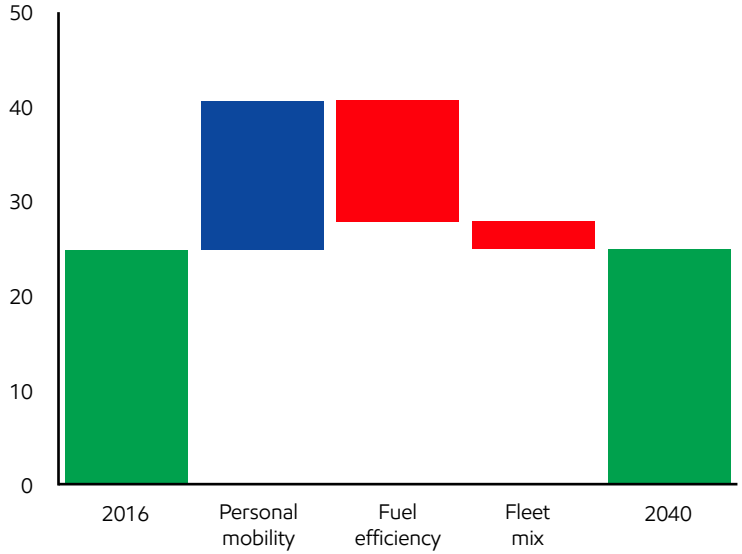
Access to personal mobility increases

Vehicles per thousand people



Efficiency mitigates light-duty demand growth

Global light-duty vehicle transportation demand – MBDOE



- As incomes rise, individuals want more personal mobility, so demand for cars and motorcycles increases
- Motorcycles offer a lower-cost entry point to personal mobility, with ownership particularly high in Asia Pacific
- Car ownership significantly increases in non-OECD countries, with Asia Pacific leading the growth
- In the OECD, while total vehicle ownership increases significantly, the number of cars per 1,000 people increases only about 10 percent

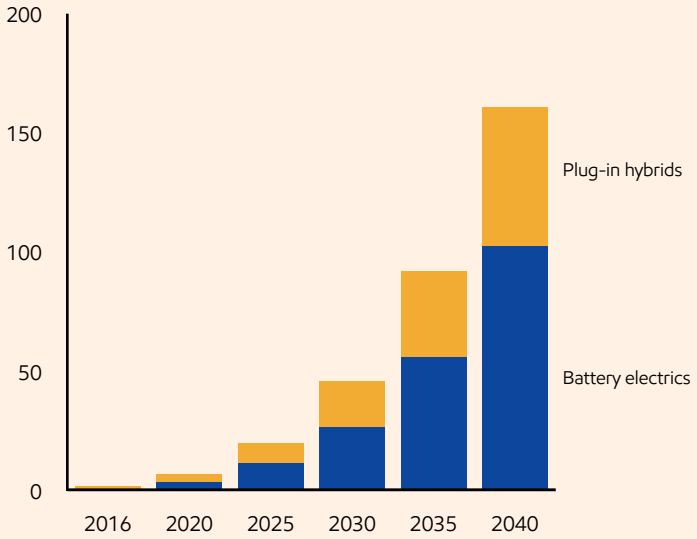
- Increasing access to vehicles drives a worldwide increase in personal mobility-related energy demand growth
- Assuming the current fleet mix and fuel efficiency, there would be a significant increase in energy demand for personal mobility
- However, major gains in the fuel efficiency of conventional vehicles leads to a major reduction in the energy needed
- Changes in the fleet mix (e.g., increasing hybrids and electric vehicles) play a much smaller role in limiting energy demand for light-duty vehicles

Demand

Transportation – projections

Electric vehicles grow rapidly

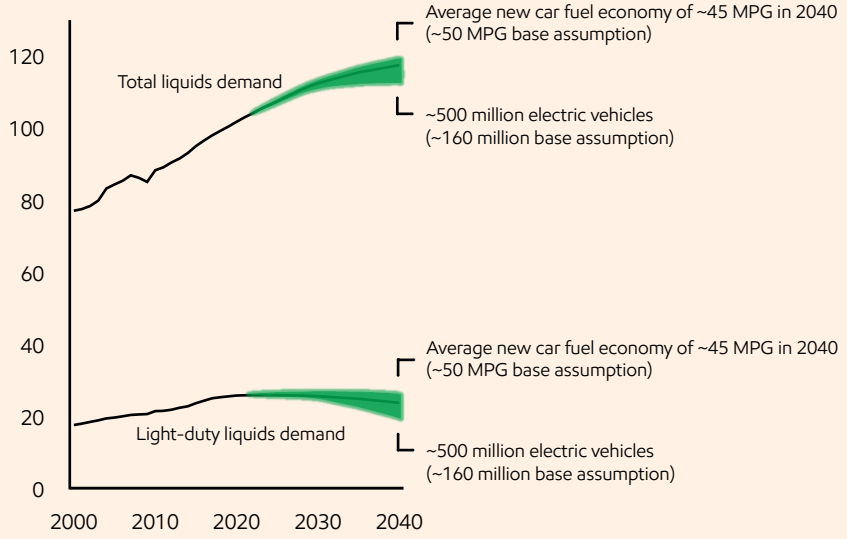
Worldwide electric vehicle fleet – million cars



- Currently there are approximately 2 million electric vehicles in the global fleet, or about 0.2 percent of the total
- Recently, some car manufacturers and governments have announced plans to limit future vehicle sales to those with an electric motor, including hybrids, plug-in hybrids and battery electric vehicles
- The electric vehicle fleet will see strong growth driven by decreasing battery costs, increasing model availability and continued support from government policies
- Future battery costs and government policies are uncertain, hence there is a wide range of perspectives on future electric vehicle growth, with third-party estimates for 2040 ranging from a factor of three higher and lower than the *Outlook*

Liquids demand trajectory uncertain but resilient

World – MBDOE



Shaded ranges are indicative of potential shifts in demand relative to base *Outlook*

- Sensitivities help assess potential impacts to light-duty liquids demand using alternate assumptions around electric vehicle penetration, changes in fuel efficiency or broader mobility trends
- For every additional 100 million electric vehicles on the road in 2040, liquids demand could fall by ~1.2 million barrels per day; if the entire light-duty fleet is electrified in 2040, total liquids demand could be approximately the same as in 2013 (see page 42)
- Alternatively, recent consumer preferences have slowed the increase in fuel efficiency of new vehicle sales in both the OECD and non-OECD
- While the *Outlook* forecasts new car fuel efficiency trends will be well aligned with government policies, a continuation of recent trends in consumer preferences could add more than 2 million barrels per day of liquids demand by 2040

Residential and commercial

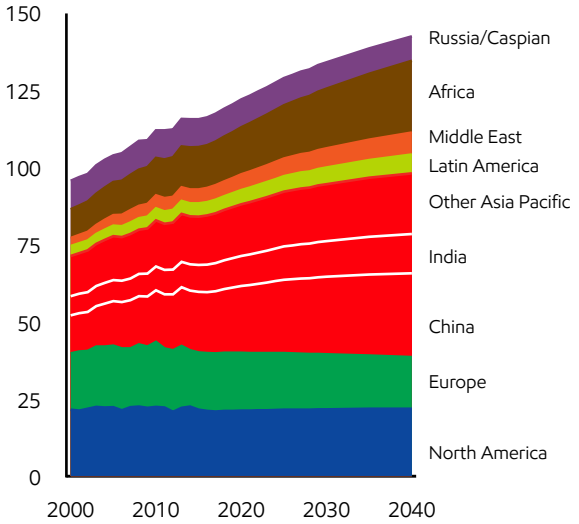
As populations grow and prosperity rises around the world, we will need more energy to power homes, offices, schools, shopping centers and hospitals. Combined residential and commercial energy demand is projected to rise by more than 20 percent through 2040. About 90 percent of this demand growth will be met by electricity. Led by the growing economies of non-OECD nations, average worldwide household electricity use will rise about 30 percent between 2016 and 2040.

Energy efficiency plays a big role within the residential and commercial sectors as modern appliances, advanced materials and policies shape the future.

Residential and commercial – projections

Residential and commercial demand shifts to non-OECD

Demand by region – BTUs



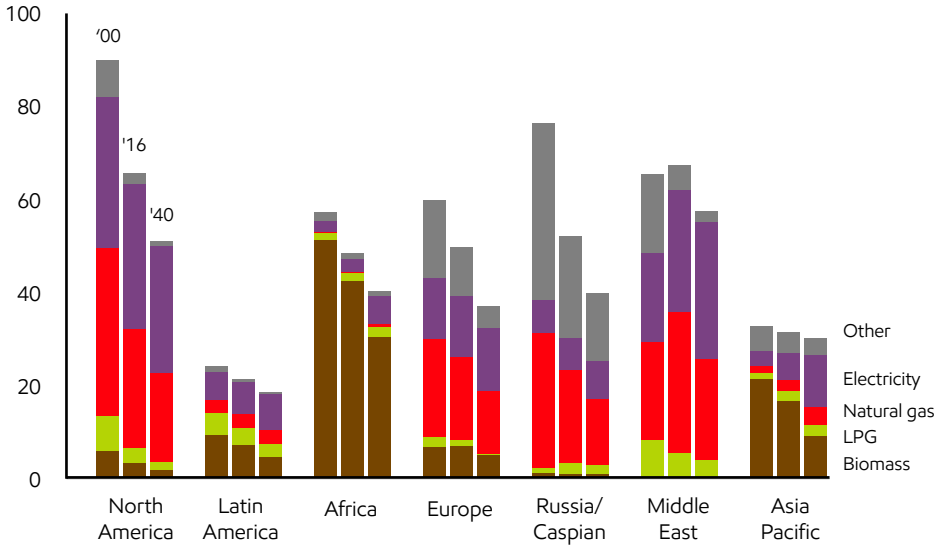
- Growth in households, rising prosperity and expanding commercial activity will spur demand for lighting, heat and power in homes and offices
- Residential and commercial energy demand will rise over 20 percent by 2040, consistent with overall population growth
- Essentially all growth will be in non-OECD nations, where demand will rise close to 40 percent
- Africa and China will each account for about 30 percent of the increase in residential and commercial energy demand

Demand

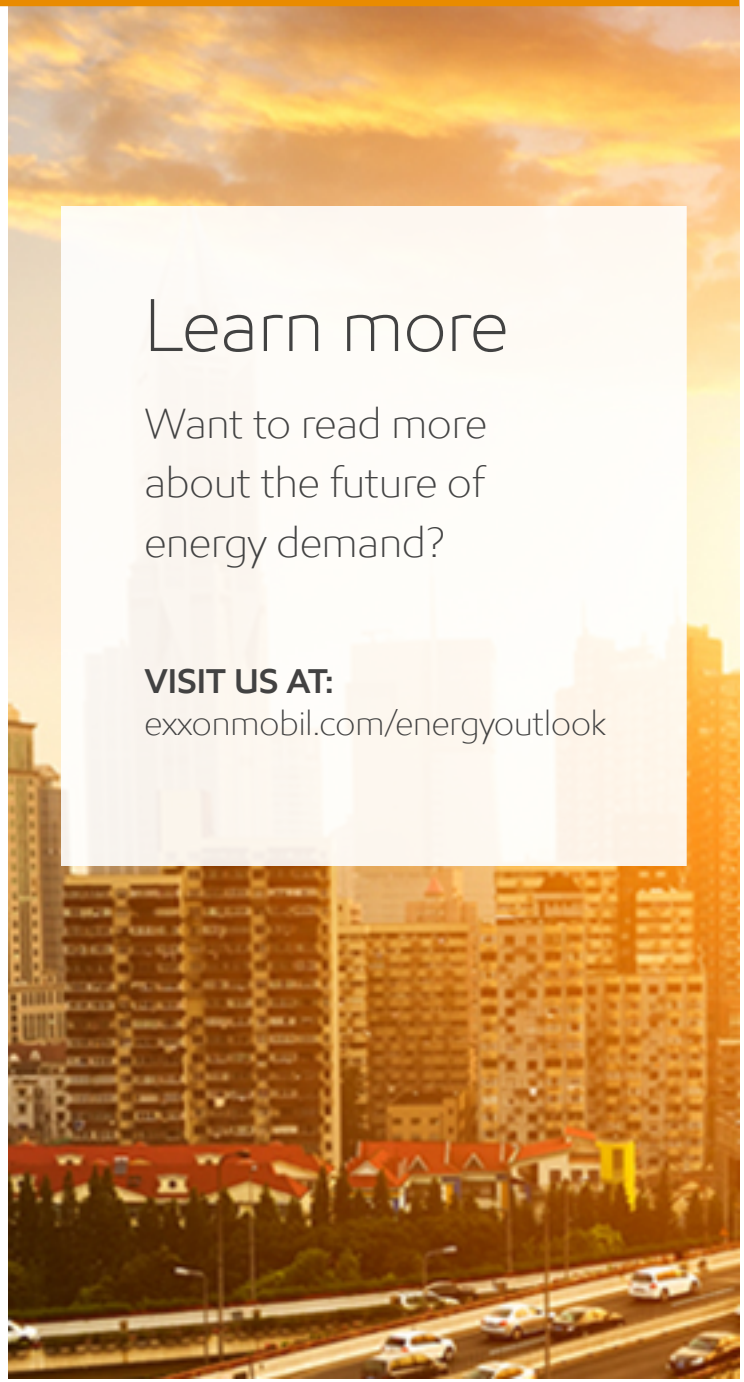
Residential and commercial – projections

Residential energy use reflects efficiency gains

Million BTUs per household per year



- Household energy use continues to improve, reflecting more efficient buildings appliances and consumer products
- Demand for electricity is growing across all regions
- People in Africa and Asia Pacific still rely on biomass products to a large degree; more than 2.5 billion people worldwide lack access to modern energy for cooking, and about 1 billion people lack access to electricity



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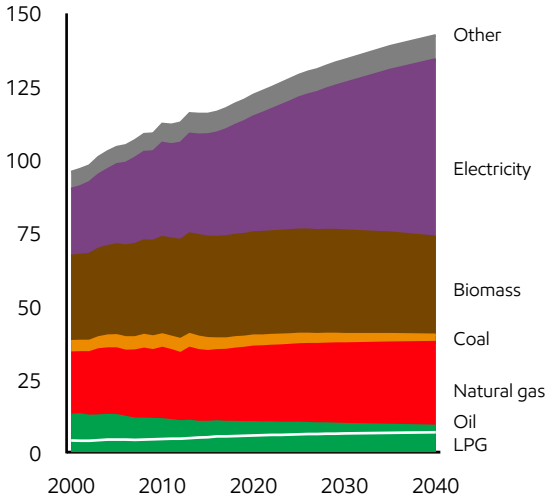
Demand

Residential and commercial – projections

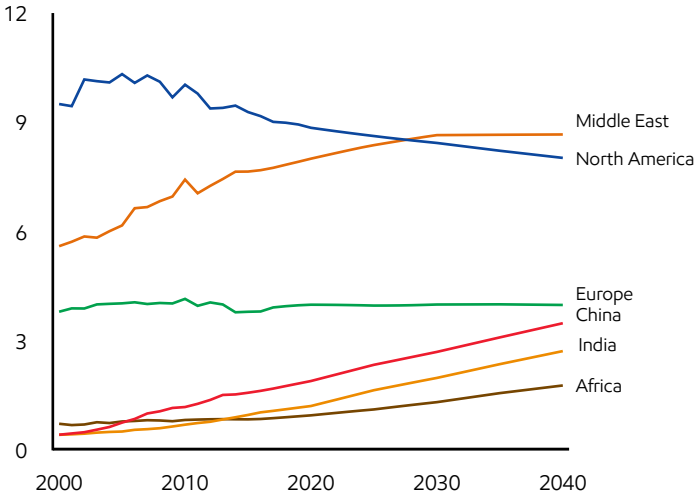
Electricity demand surges

Residential and commercial energy demand
World – quadrillion BTUs



Household electricity up in non-OECD

Residential electricity intensity
Megawatt hours per household per year



- Energy shifts reflect rising living standards and increasing urbanization through 2040
- Electricity use increases 70 percent, accounting for nearly all the growth in total energy demand from 2016 to 2040; electricity reaches a share of 40 percent in 2040
- Natural gas use grows about 20 percent, keeping its share around 20 percent through 2040
- Oil demand decreases, though usage of liquefied petroleum gas increases as a cooking fuel replacing biomass
- Biomass demand peaks, aided by growing access to modern energy in non-OECD nations

- Residential electricity use will rise about 75 percent by 2040, driven by a nearly 150 percent increase in non-OECD nations
- Electricity use per household will rise about 30 percent globally, as household use in non-OECD countries rises about 70 percent
- Electricity use per household in OECD nations will be flat-to-down as efficiencies help limit electricity requirements
- Residential electricity use in Africa and India is likely to increase about 250 percent, though both areas will continue to lag in terms of electricity per household

Industrial

Energy and industry have a long history together, and their future remains intertwined. Energy fuels industries of all kinds, from microchip manufacturing to skyscraper construction, food processing to pharmaceuticals, agriculture to zero-emission vehicle production. Consumer demand for the many and varied products that industries offer has provided the impetus to unlock new sources of energy supply from the industrial revolution to the shale revolution.

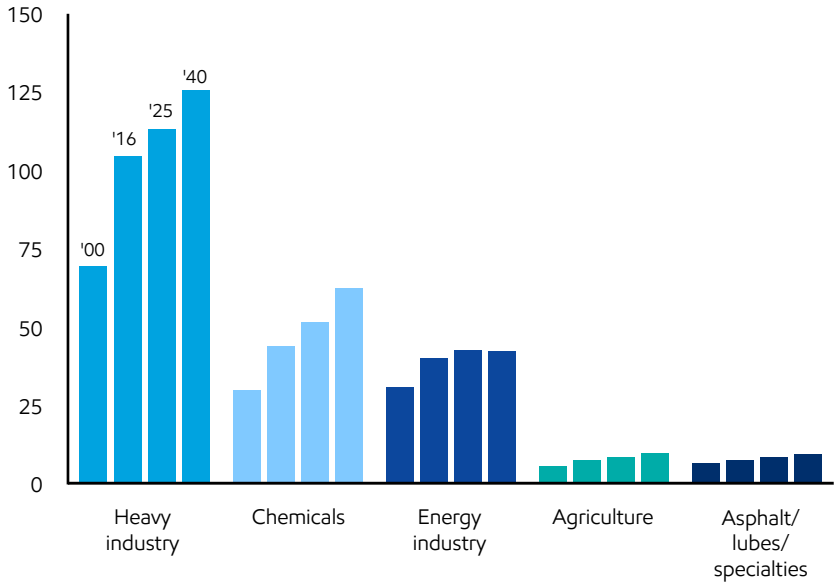
As global prosperity continues to expand, industrial energy demand will increase. Most of the growth occurs in emerging markets. The chemicals industry is the industrial sub-sector with the highest rate of growth, as demand for plastics and other petrochemical products outpaces GDP in many regions.

Industrial energy demand growth would be much higher if not for the persistent pursuit of energy efficiency improvements. The *Outlook* anticipates technology advances, as well as the increasing shift toward cleaner-burning fuels such as electricity and natural gas.

Industrial – projections

Industry undergirds global economic expansion

World – quadrillion BTUs



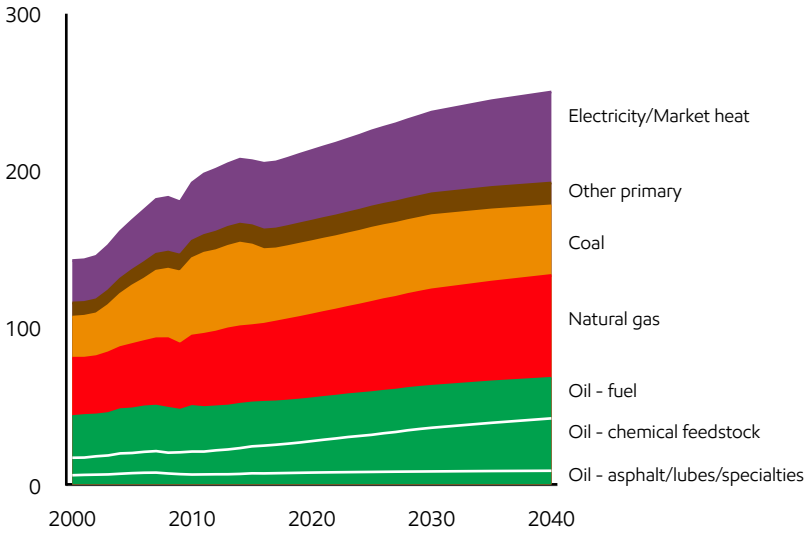
- The industrial sector includes the energy used to build cities, power factories, refine fuels and produce food
- Manufacturing jobs contribute to rising prosperity, while also making products to meet consumer preferences for cars, clothing, cosmetics and computers
- Almost half of the world's energy is used for industrial activity
- Overall, industrial energy demand rises about 20 percent from 2016 to 2040; the chemicals sector grows 40 percent
- Improving industrial energy efficiency conserves fuel and reduces emissions

Demand

Industrial – projections

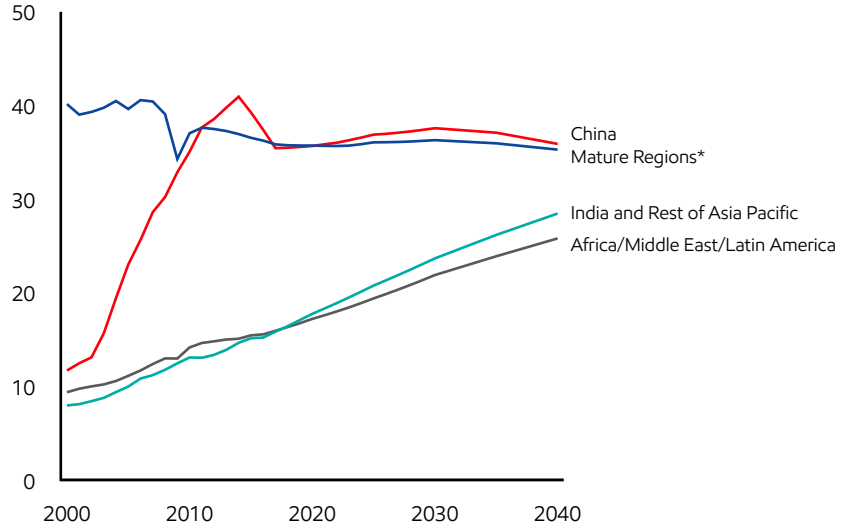
Oil, gas and electricity fuel industrial growth

World – quadrillion BTUs



Heavy industry migrates to emerging markets

Quadrillion BTUs



*Mature Regions include North America, Europe, Russia/Caspian and OECD Asia Pacific

- Industry uses energy both as a fuel and as a feedstock for chemicals, asphalt lubricants, waxes and other specialty products
- Industrial fuel powers boilers, motors, compressors, robots, forklifts and cranes
- Oil, natural gas and electricity each contribute about one-third of industrial energy growth; oil growth is mostly due to its use as a chemical feedstock
- Use of coal and oil as industrial fuels declines in favor of natural gas and electricity, as companies strive to reduce their direct emissions
- Coal continues to play a role in steel and cement manufacturing

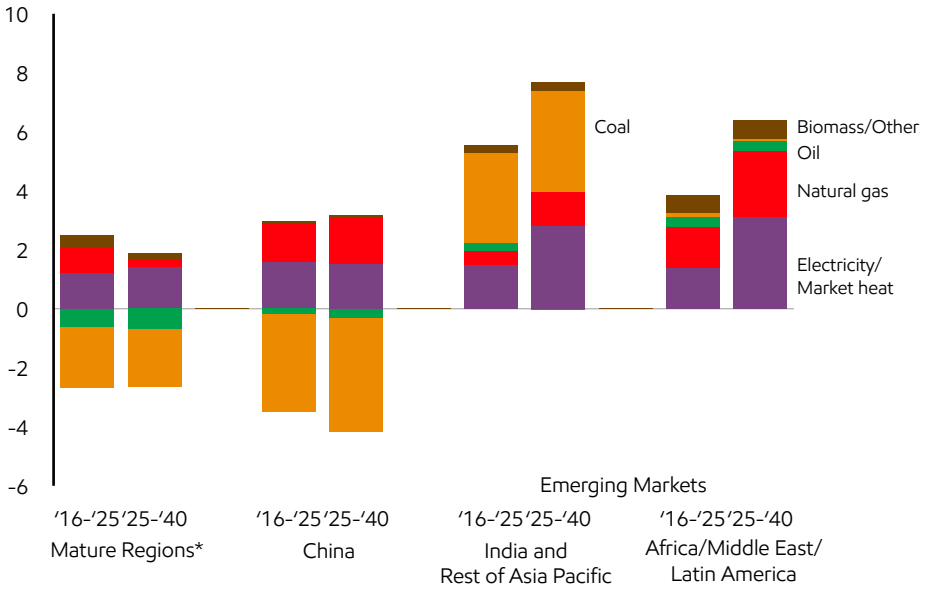
- Steel, cement and manufacturing are essential to urban infrastructure development
- Heavy industry demand rises steadily in emerging markets in Asia, Africa, the Middle East and Latin America
- China's path forward mirrors the mature regions, as its economy transitions to higher value manufacturing and services after a decade of soaring, energy-intensive growth
- Demand grows by 75 percent in the emerging markets, but is essentially flat in the mature regions and China

Demand

Industrial – projections

Heavy industry energy evolves toward cleaner fuels

Growth in quadrillion BTUs

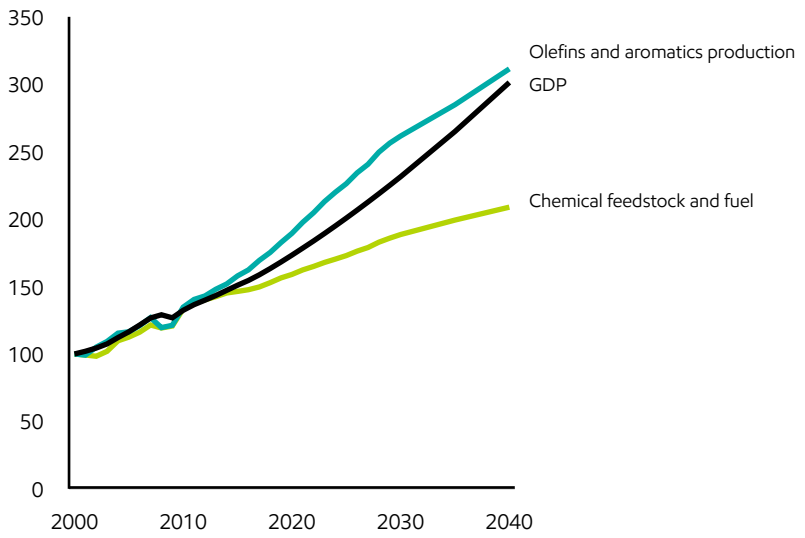


*Mature Regions include North America, Europe, Russia/Caspian and OECD Asia Pacific

- New industry is attracted to regions with access to abundant, affordable energy, an able workforce and balanced policies
- Electricity and natural gas are manufacturers' fuels of choice because of their convenience, versatility and lower direct emissions
- Climate policies boost natural gas demand in mature markets; air quality management spurs switching from coal to natural gas in China
- Abundant natural gas supplies give manufacturers a competitive edge in Africa, the Middle East and parts of Latin America
- Coal's use declines in China but doubles in coal-producing India and emerging Asia

Consumer demand propels chemicals growth

World – index, 2000=100



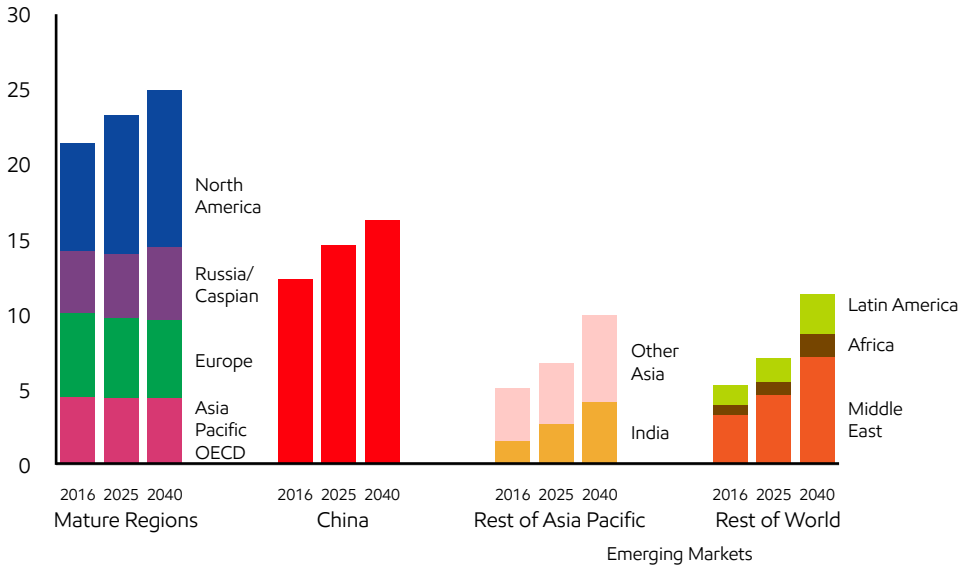
- Consumer demand for plastics, fertilizer and other chemical products increases with rising incomes
- Olefins and aromatics are basic building blocks for plastics, adhesives and other consumer products; consumer demand outpaces GDP growth
- Manufacturers see plastics as light-weight, durable materials that can improve the performance of their products, from packaging to auto parts to medical devices
- The chemicals sector uses energy both as a fuel and as a feedstock
- Chemicals energy demand grows by 40 percent from 2016 to 2040

Demand

Industrial – projections

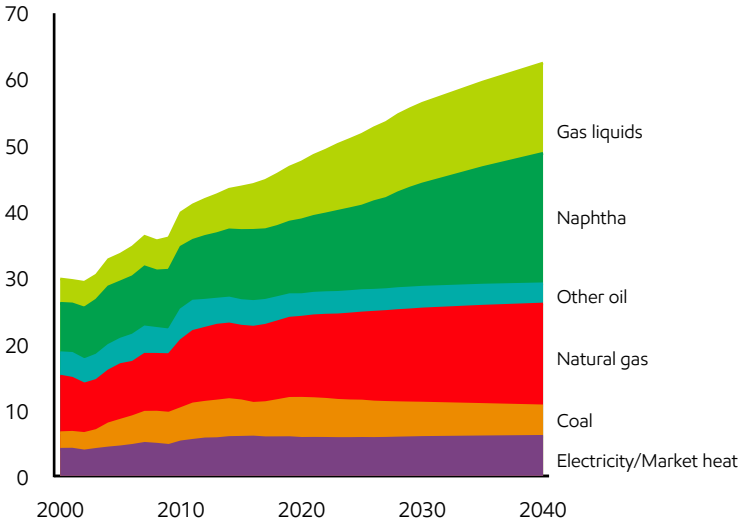
Rising prosperity lifts chemicals energy demand

Quadrillion BTUs



Chemicals production relies on oil and natural gas

World – quadrillion BTUs



- Since chemicals production is energy-intensive, there is usually a competitive advantage for manufacturers to locate plants near low-cost feedstock and fuel sources
- The U.S. chemicals industry expands using abundant, low-cost natural gas liquids which are largely a byproduct of unconventional oil and natural gas production
- Asia Pacific's petrochemical production grows as rising incomes stoke consumer demand
- Affordable energy (feedstock and fuel) supplies prompt investment in the Middle East Africa and Latin America; chemicals industry energy use more than doubles in each region
- Mature regions remain important contributors to global chemicals production

- Feedstock comprises about two-thirds of chemicals energy demand; fuel one-third
- Oil and natural gas account for about 75 percent of chemicals energy demand today, and nearly all of the growth from 2016 to 2040
- Naphtha and natural gas liquids are primarily used as feedstock; natural gas is used as both a feedstock (notably for fertilizer) and a fuel
- Natural gas liquids consumption about doubles from 2016 to 2040, as unconventional oil and natural gas production in the United States expands supply
- Naphtha remains the dominant feedstock in Asia; the Middle East relies on natural gas liquids and natural gas

Electricity and power generation

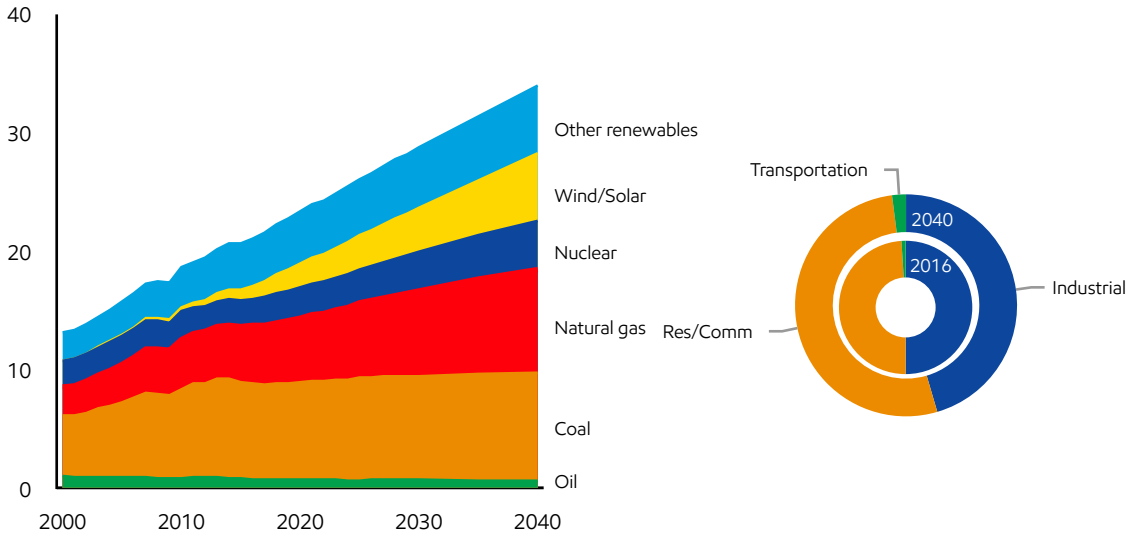
Demand for electricity continues to rise as it is the energy used in powering wide applications ranging from lighting to home appliances to global e-commerce and digital services. Power generation uses the broadest array of fuels: coal, natural gas, nuclear and renewables such as hydroelectricity, solar and wind.

As electricity use rises, the types of fuels used to generate electricity will shift, globally and regionally. Policies seeking to address climate change and air quality will influence the choice of sources, with wind and solar, natural gas, and nuclear fueling growth in power generation.

Electricity and power generation – projections

Electricity sources shift

World – thousand TWh (net delivered)



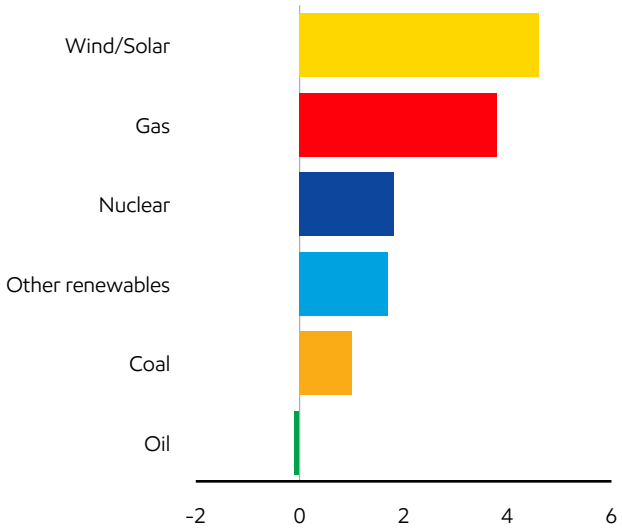
- Global electricity demand grows by 60 percent from 2016 to 2040, driven by demand in the residential and commercial, industrial and transportation sectors
- Industrial share of demand reduces as China's economy shifts from heavy industry to services and lighter manufacturing; transportation's share doubles to 2 percent in 2040
- The world shifts to lower carbon sources for electricity generation, led by natural gas, renewables such as wind and solar, and nuclear
- Coal provides less than 30 percent of the world's electricity in 2040, down from about 40 percent in 2016

Demand

Electricity and power generation – projections

Natural gas and renewables dominate growth

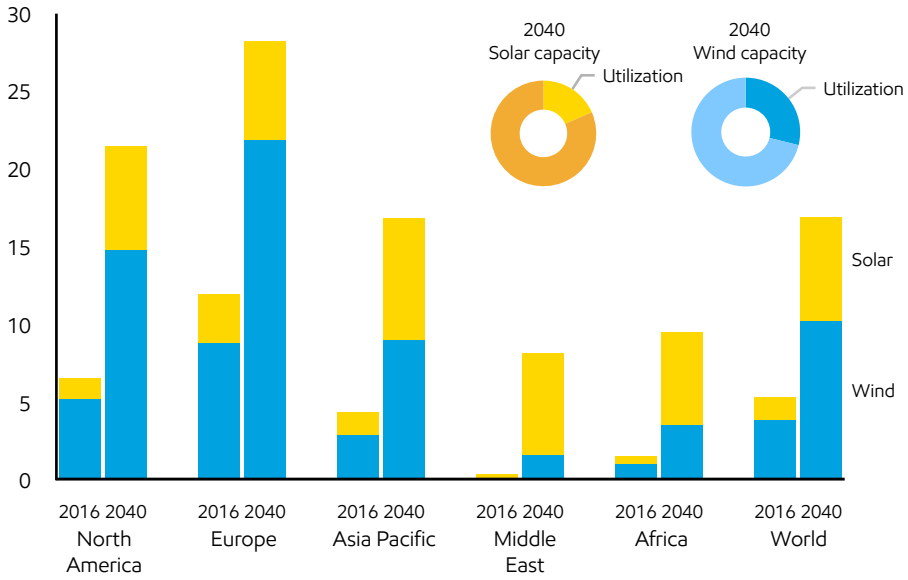
Global growth 2016-2040 – thousand TWh (net delivered)



- Wind and solar grow significantly, supported by policies to reduce CO_2 emissions as well as cost reductions, and lead growth as sources for electricity generation
- Natural gas grows significantly, with growing demand from OECD countries, China and countries where natural gas is domestically available
- Nuclear demand grows, with more than 50 percent of this growth coming from China
- Hydropower growth makes up more than 80 percent of growth in the other renewables category
- Coal-fired generation grows in many Asia Pacific countries due to electricity demand growth as well as favorable economics and supportive policy environments

Renewables penetration increases across all regions

Wind/solar share of delivered electricity percent – share of TWh



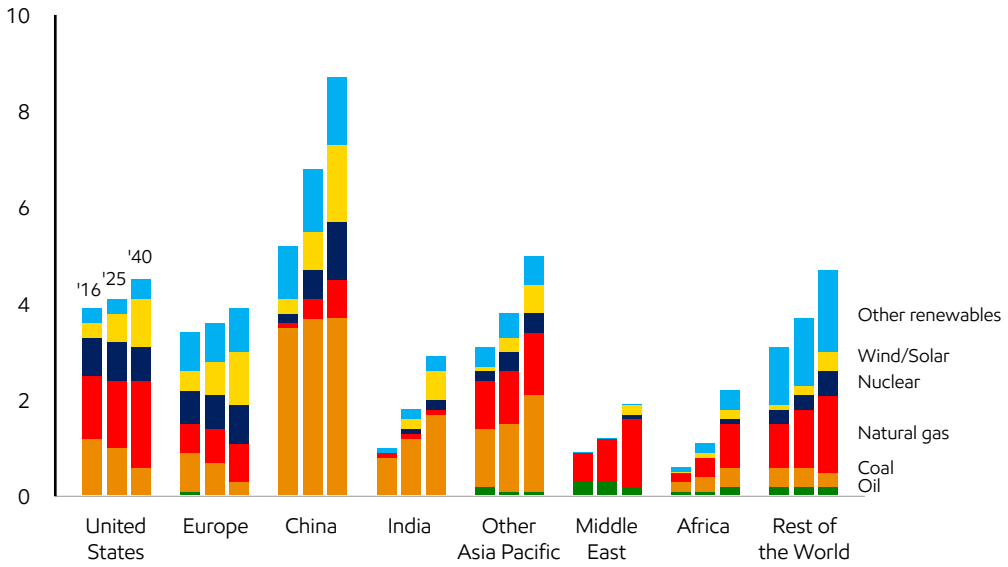
- Globally, wind and solar's share of delivered electricity grows significantly from about 5 percent in 2016 to about 17 percent in 2040
- Wind and solar see strong growth in North America and Europe, and provide more than 20 percent of delivered electricity in 2040
- Renewables growth in Asia Pacific supports local air quality and energy diversity goals
- The Middle East and Africa see growth in solar due to reduced costs and favorable solar resource
- While capacity utilization improves over time, intermittency still limits worldwide wind and solar utilization to about 30 percent and 20 percent respectively in 2040

Demand

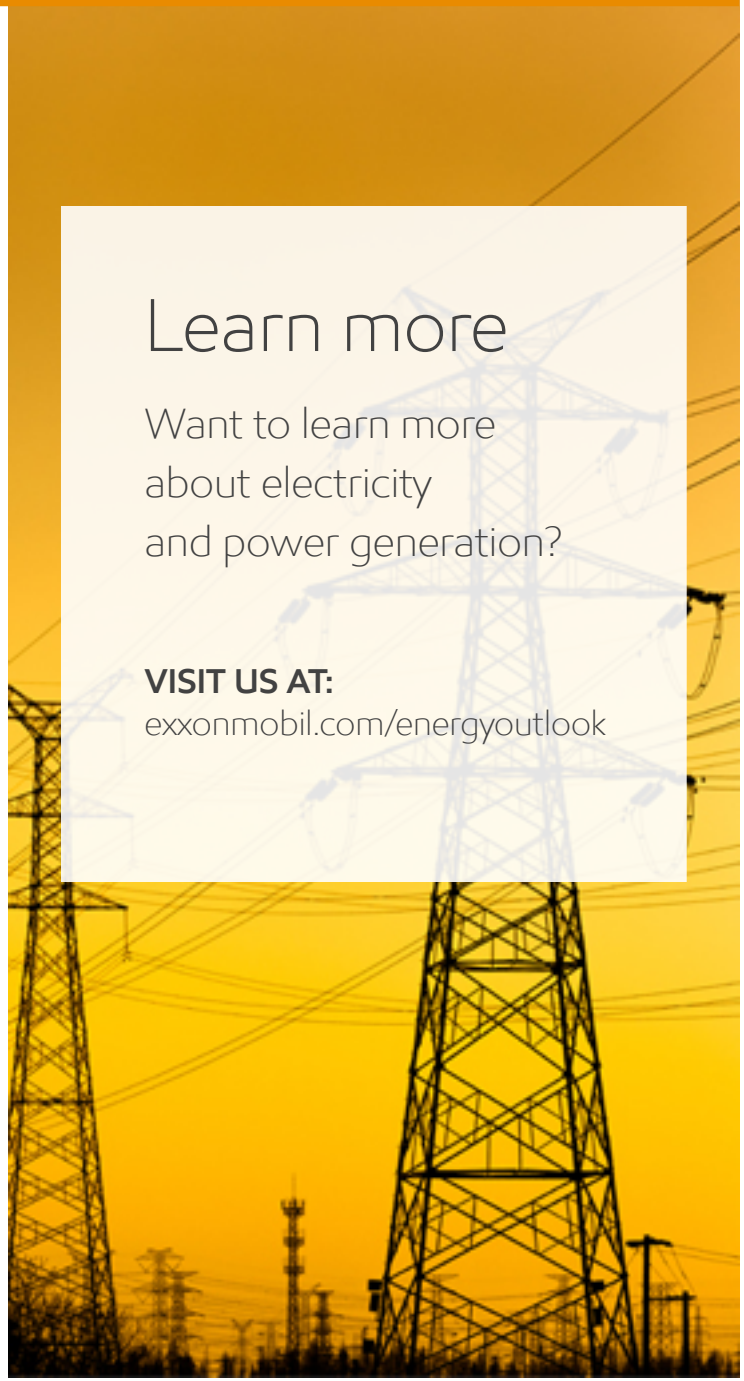
Electricity and power generation – projections

Electricity generation highlights regional diversity

Net delivered electricity – thousand TWh



- About 60 percent of the growth in electricity demand will come from Asia Pacific
- Mix of electricity generation sources will vary significantly by region
- The United States and Europe lead shift away from coal, with significant gains in natural gas, wind and solar
- China's coal share of electricity generation falls with nuclear, renewables and natural gas meeting close to all electricity demand growth
- The Middle East, Africa and the rest of world draw on natural gas where domestically available
- Favorable economics drive coal-fired electricity in Asia Pacific; India's use of coal for electricity more than doubles from 2016 to 2040



Learn more

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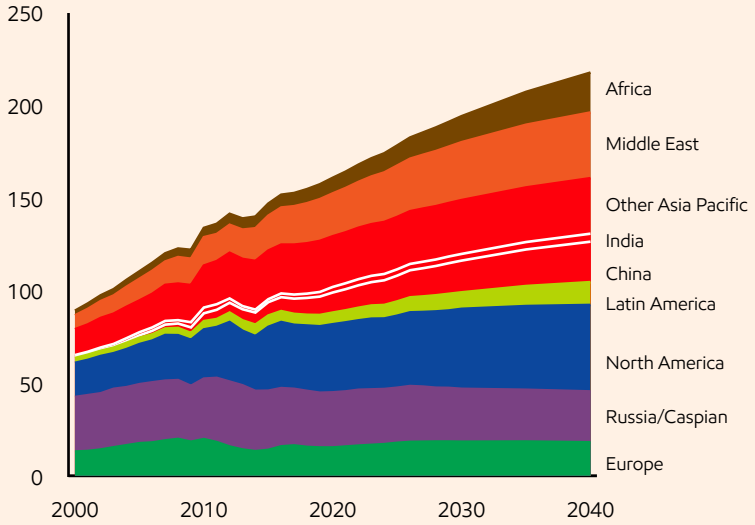
Demand

Electricity and power generation – projections

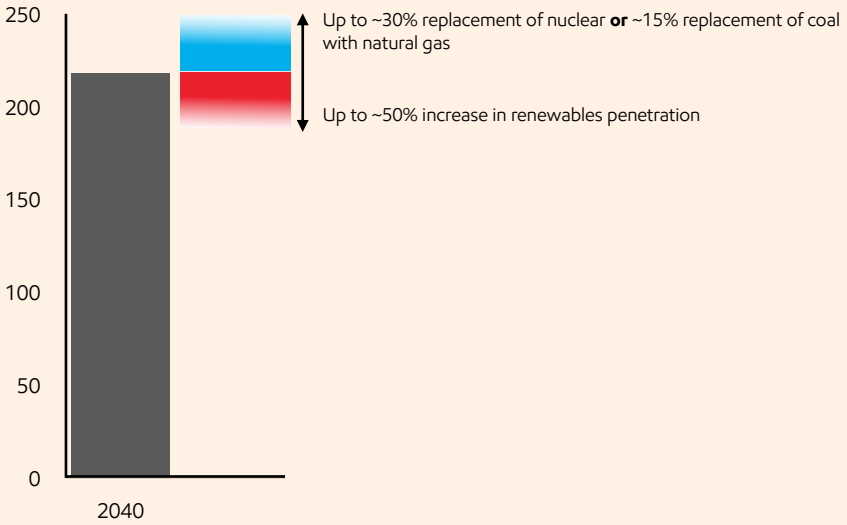
Natural gas is a key fuel for reliable electricity generation

Natural gas demand for electricity generation – billion cubic feet per day (BCFD)



Different policy or technology choices can impact outcome

Global natural gas demand for electricity generation sensitivity – BCFD



Shaded ranges are indicative of potential shifts in demand relative to base *Outlook*

- Natural gas is reliable and efficient for baseload electricity generation; its flexibility also makes it well suited to meet peak demand and back-up intermittent renewables
- The role of natural gas in the electricity generation mix varies by country: natural gas-rich regions rely heavily on natural gas-fired electricity, while importing regions balance the use of natural gas with other fuels
- The *Outlook* reflects ExxonMobil's best views of technology improvements and policy evolution; sensitivities test the impact of alternate pathways on natural gas demand for electricity generation
- An accelerated deployment of solar and wind due to swifter cost declines and/or even more generous, targeted-support policies could reduce natural gas demand
- Conversely, stronger public sentiments against nuclear or coal and/or a shift toward more technology-neutral carbon abatement policies could increase the role of natural gas for baseload electricity generation

2018 Outlook for Energy

Emissions

Providing reliable, affordable energy to support prosperity and enhance living standards is coupled with the need to do so in ways that reduce impacts on the environment, including the risks of climate change. This is a dual challenge ExxonMobil takes seriously.

The challenge of meeting global energy needs and managing the risks of climate change is real – and daunting. Real in that billions of people need reliable, affordable energy every day, and daunting in the fact that people and governments in every nation have a variety of important goals and limited financial resources to address them. Progress on energy and climate objectives requires practical approaches that will contribute to both without stifling economic costs.

Governments bear a unique responsibility in this regard. A key challenge is to develop and implement policies that focus emission-reduction efforts on low-cost options. This approach will help promote better living standards while reducing emissions.

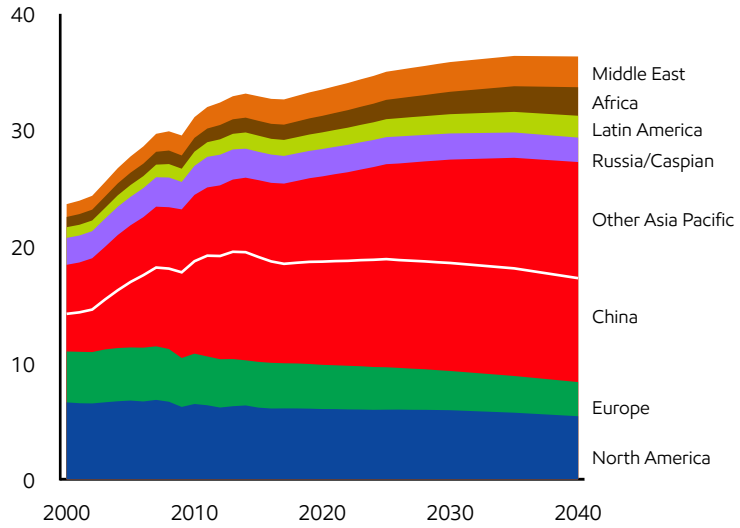
The long-term nature of the climate challenge promises an evolution of available solutions as knowledge expands, technology advances and markets adapt. Policies that promote innovation and flexibility afforded by competition and free markets will be critical to help ensure nations pursue the most cost-effective opportunities to reduce global GHG emissions and meet people's energy needs.

Emissions

Emissions – projections

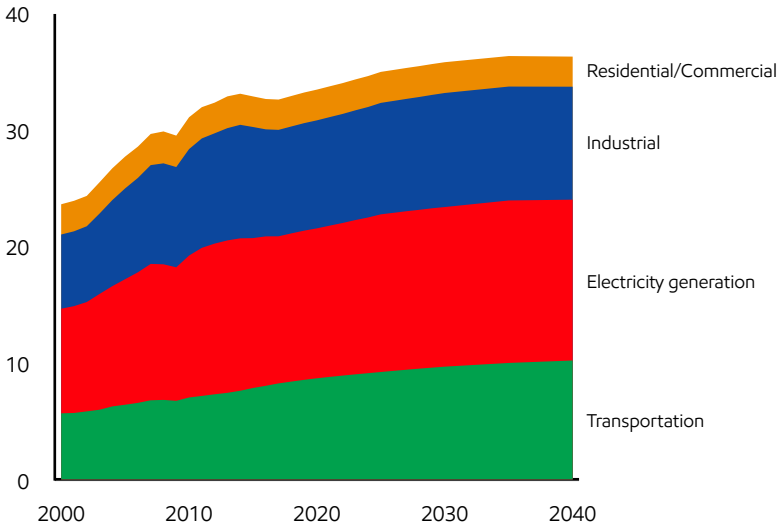
Energy-related CO_2 emissions peak

Billion tonnes



All sectors contributing to restrain CO_2 emissions growth

Global energy-related CO_2 emissions - billion tonnes



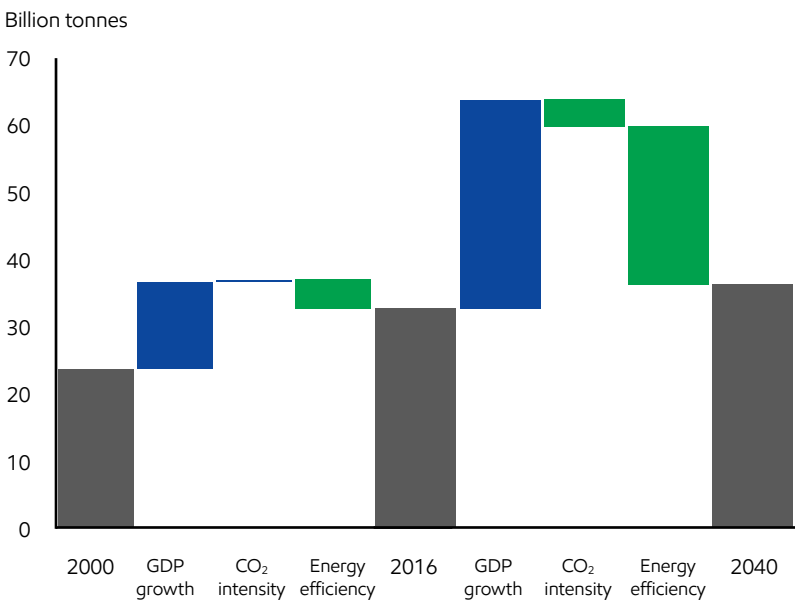
- Global CO_2 emissions rose close to 40 percent from 2000 to 2016, despite a roughly 10 percent decline in emissions in Europe and North America
- Global CO_2 emissions are likely to peak by 2040, at about 10 percent above 2016 levels
- Combined CO_2 emissions in Europe and North America fall about 15 percent by 2040 versus 2016
- China contributed about 60 percent of the growth in emissions from 2000 to 2016; its emissions peak about 2030, and gradually decline toward the 2016 level in 2040
- Emissions outside North America, Europe and China rise about 35 percent from 2016 to 2040, with the share of global emissions reaching 50 percent by 2040

- Electricity generation accounts for about 40 percent of energy-related CO_2 emissions; shift to less carbon-intensive sources of electricity (e.g. wind, solar, nuclear and natural gas) will help reduce the CO_2 intensity of delivered electricity by more than 30 percent
- Transportation represents about 25 percent of CO_2 emissions, and this share is likely to grow modestly to 2040 driven by expanding commercial transportation activity
- Light-duty vehicle CO_2 emissions are expected to decline close to 10 percent from 2025 to 2040 as more efficient conventional vehicles and electric cars gain significant share
- Industrial sector activities account for about 30 percent of CO_2 emissions; over the outlook, efficiency gains and growing use of less carbon-intensive energy will help reduce industrial CO_2 emissions relative to GDP by about 50 percent

Emissions

Emissions – projections

Restraining global energy-related CO_2 emissions



- The primary driver of increasing global CO_2 emissions between 2000 and 2016 was economic growth, as global GDP expanded about 55 percent
- Improving energy efficiency across economies (energy use per unit of GDP) helped slow the growth in emissions, while CO_2 intensity of energy use remained fairly constant
- As economic growth continues to drive CO_2 emissions through 2040, efficiency gains and a shift to less CO_2-intensive energy will each help substantially moderate emissions
- As the world's economy nearly doubles by 2040, energy efficiency gains and a shift in the energy mix will contribute to a nearly 45 percent decline in the carbon intensity of global GDP

Learn more

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2018 Outlook for Energy

Supply

What resources will be available to meet the world's increasing demand for more energy?

Technology advancements underpin the diversification of energy choices. The supply mix to meet growing energy demand will be historically diverse – from the oil and natural gas in America's shale regions, to the deepwater fields off Brazil; from new nuclear reactors in China, to wind turbines and solar arrays in nations around the world.

This diversification in global energy supply will grow over the next two-and-a-half decades. Society's push for lower-emission energy sources will drive substantial increases in renewables such as wind and solar. By 2040, nuclear and all renewables will be approaching 25 percent of global energy supplies.

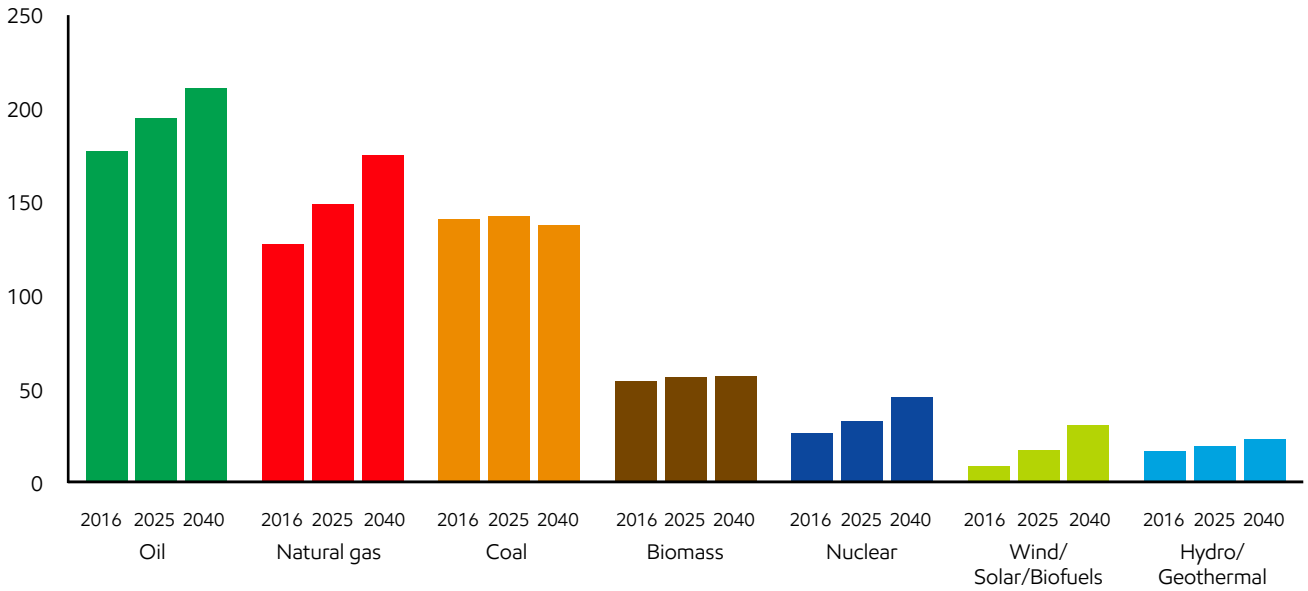
Oil grows and continues to be the primary source of energy for transportation and as a feedstock for chemicals. Natural gas also grows, with increasing use in power generation, as utilities look to switch to lower-emissions fuels. Coal struggles to grow due to increased competition in power generation from renewables and natural gas, led by declines in OECD nations.

Supply

Supply – projections

Energy supply evolves to meet diverse demand

Global demand by fuel – quadrillion BTUs



- Technology improvements lead to wind, solar and biofuels increasing, with a combined growth of about 5 percent per year
- Non-fossil fuels reach about 22 percent of total energy mix by 2040
- Oil continues to provide the largest share of the energy mix; essential for transportation and chemicals
- Natural gas demand rises the most, largely to help meet increasing needs for electricity and support increasing industrial demand
- Oil and natural gas continue to supply about 55 percent of the world's energy needs through 2040
- Coal's share falls as OECD countries and China turn to lower-emission fuels
- Nuclear demand grows 70 percent between 2016 and 2040, led by China
- Wind, solar and biofuels reach about 5 percent of global energy demand

Liquids

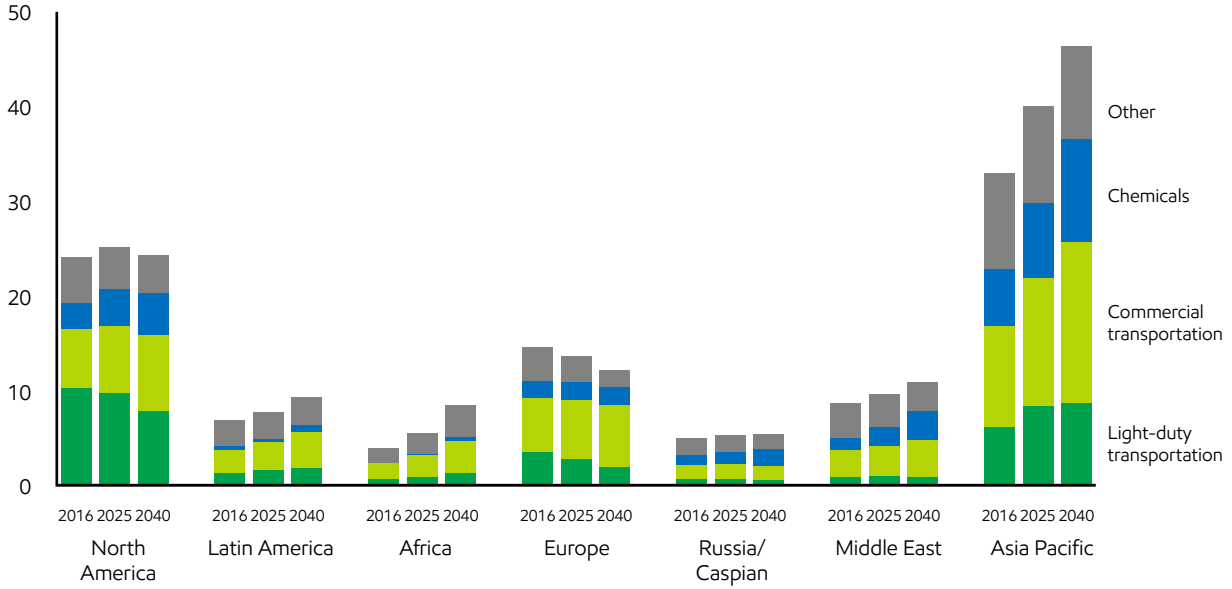
Liquids demand is expected to grow by about 20 percent over the next two-and-a-half decades, driven by the transportation and chemicals sectors.

To meet the demand, supply growth will come from diverse sources, with technology advancements a key enabler. Technology enables growth in supply from tight oil and natural gas liquids, together reaching nearly 30 percent of global supply by 2040. Combined with growth in oil sands, energy markets shift, and North America becomes a net exporter.

Liquids – Demand

Liquids demands driven by transportation and chemicals

By region and sector – MBDOE



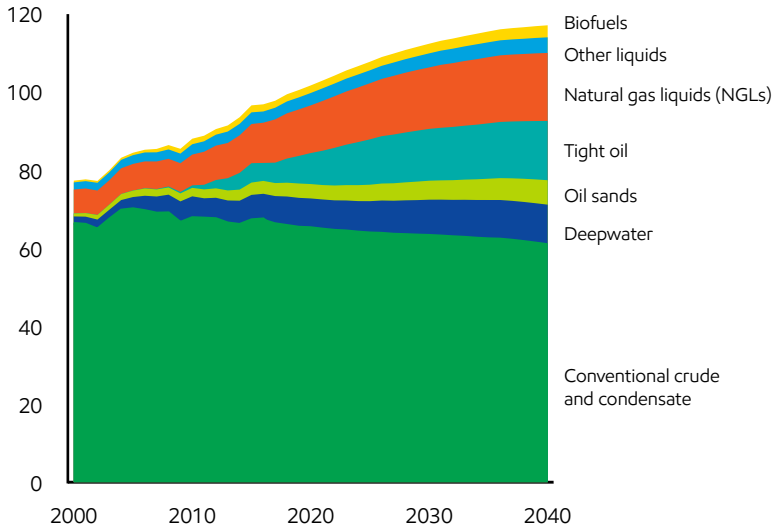
- Global liquids demand grows about 20 percent from 2016 to 2040
- Commercial transportation and chemicals sectors lead demand growth
- Advances in light-duty vehicle efficiency lead to liquids demand decline in North America and Europe
- Africa liquid demand grows by about 30 percent as emerging economies advance
- Asia Pacific accounts for nearly 65 percent of the increase in global liquids demand to 2040, surpassing the combined liquids demand of North America and Europe by 2025

Supply

Liquids – projections

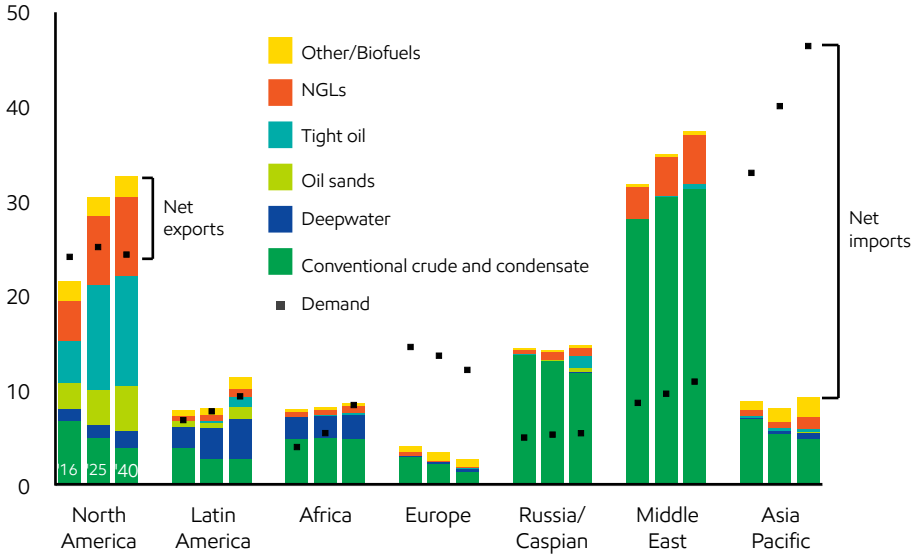
Liquids supply highlights technology gains

Global liquids supply by type – MBDOE



Liquids supply highlights regional diversity

By region and sector – MBDOE



- Global liquids production rises by 20 percent to meet demand growth
- Technology innovations lead to growth in natural gas liquids, tight oil, deepwater, oil sands and biofuels
- Technology enables efficient production from conventional sources, which still account for more than 50 percent of production in 2040
- Most growth over the *Outlook* period is seen in tight oil and natural gas liquids, which reach nearly 30 percent of global liquids supply by 2040
- Continued investment is needed to mitigate decline and meet growing demand

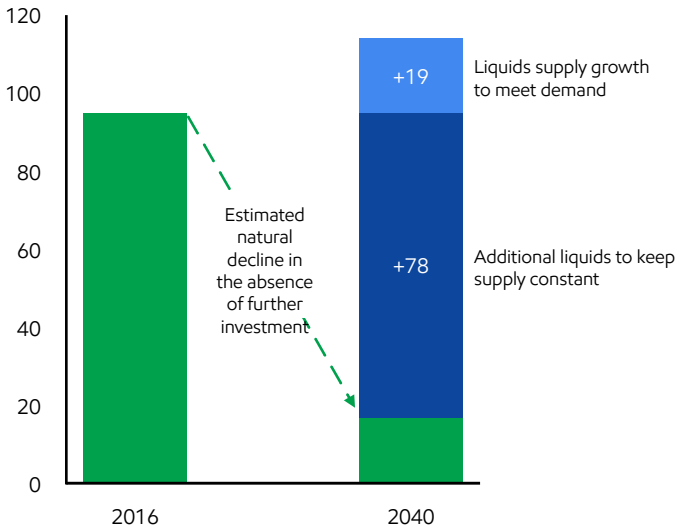
- Liquids trade balances shift as supply and demand evolve
- North America swings to a net exporter as shale growth continues
- Latin America exports increase from deepwater, oil sands and tight oil supplies
- The Middle East and Russia/Caspian remain major oil exporters to 2040, and Africa shifts to an importer
- Europe remains a net oil importer, as demand and production both decline
- Asia Pacific imports increase to 80 percent of oil demand in 2040

Supply

Liquids – projections

Liquids demand and supply warrant investment

World – MBDOE

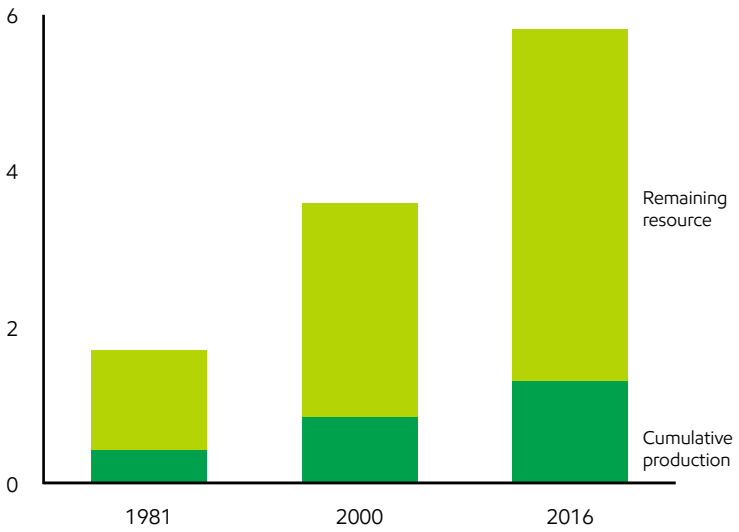


Excludes biofuels

- Without further investment, liquids supply would decline steeply
- More than 80 percent of new liquids supply needed to offset natural decline
- Per the International Energy Agency, about $400 billion a year of upstream oil investment is needed from 2017 to 2040

Technology expands recoverable resources

World – crude and condensate technically recoverable resources – trillion barrels



Sources: U.S. Geological Survey, IEA

- Global oil resources are abundant
- Oil resource estimates keep rising as technology improves
- Technology has added tight oil, deepwater and oil sands resources
- Less than one-quarter of global oil resources have been produced
- Remaining oil resources can provide about 150 years of supply at current demand

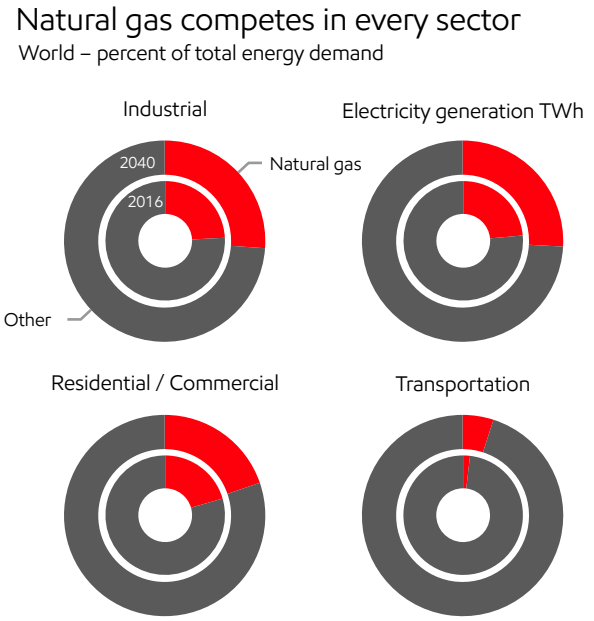
Natural gas

It is not surprising that natural gas grows more than any other energy source when one considers its abundance, convenience and many uses: home heating, fertilizer feedstock, delivery truck fuel and flexible, reliable electricity generation, just to name a few. Global natural gas demand grows by about 40 percent, as its share of the world's energy mix rises from 23 percent to 26 percent between 2016 and 2040. As a lower carbon alternative to coal, natural gas also plays a key role in the pathway to lower CO_2 emissions.

Natural gas resources are geographically and geologically diverse. Technologies, such as horizontal drilling and hydraulic fracturing, have unlocked vast unconventional resources, which have dramatically altered the natural gas supply landscape in the past decade, particularly for North America. Unconventional gas will continue to play a significant role, contributing more than half of the growth in natural gas supply to 2040.

Trade is critical to move natural gas to where consumers need it. Liquefied natural gas is well-suited to transport natural gas over long distances where pipelines are impractical. Liquefied natural gas trade will meet one-third of demand growth to 2040.

Natural gas - projections



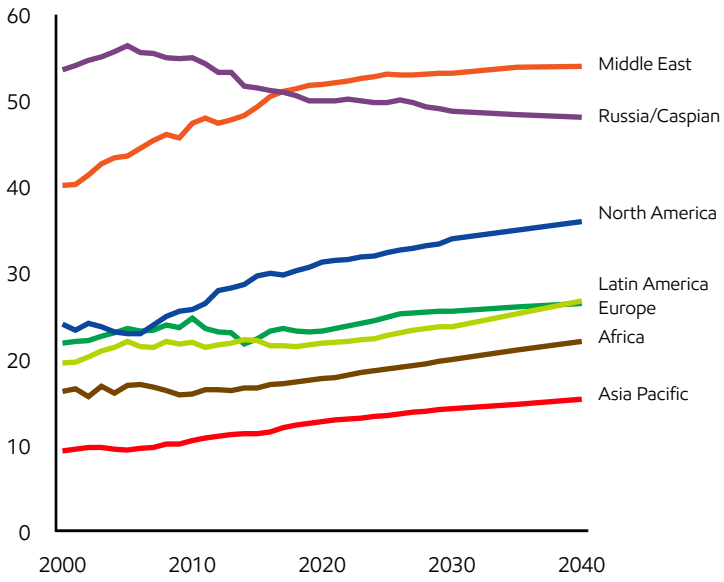
- As an abundant, versatile and cleaner-burning energy source, natural gas is increasingly a fuel of choice for homes, businesses and large-scale electricity generators
- Natural gas supplies about a quarter of the energy for industry and electricity generation in 2040
- Residential and commercial users continue to rely on natural gas as a convenient, modern fuel for heating and cooking
- Natural gas is a small fraction of transportation demand, but sees strong growth in the commercial road and marine sectors

Supply

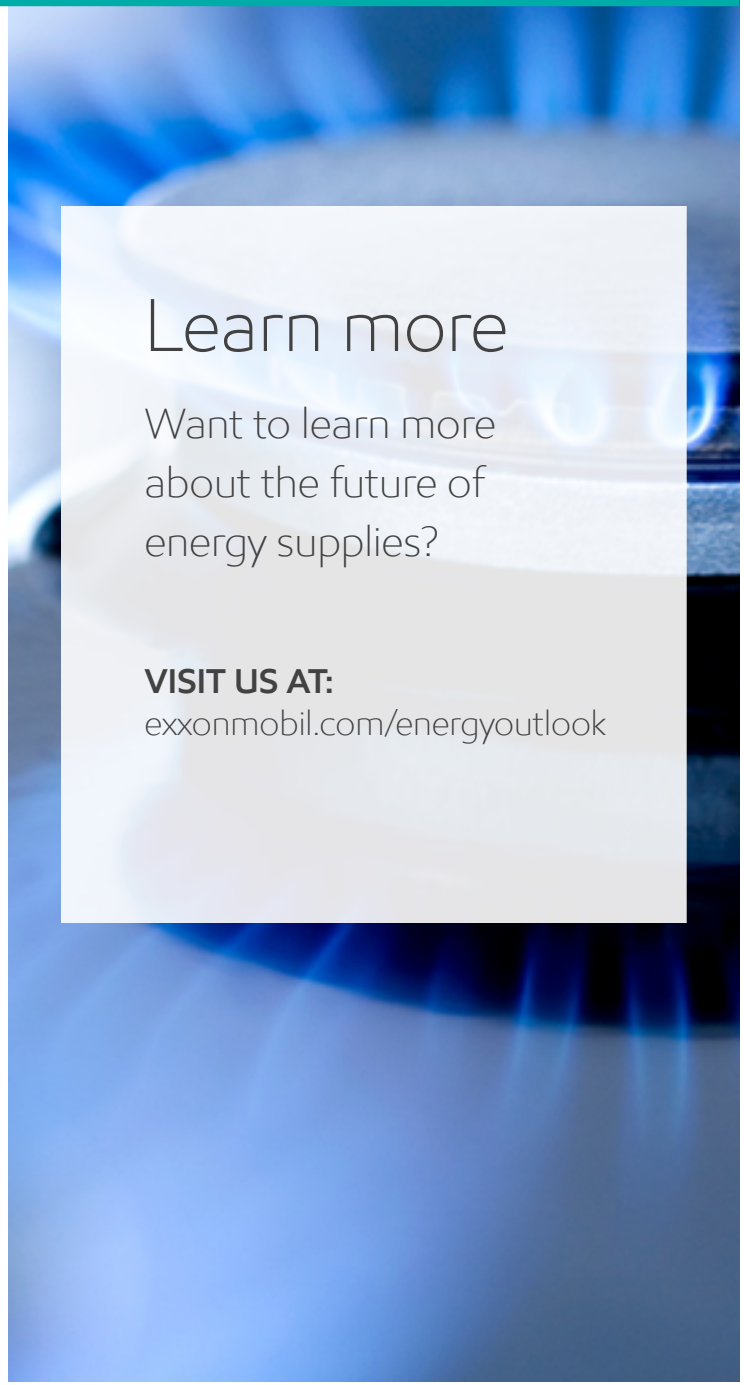
Natural gas – projections

Natural gas meets an increasing share of world demand

Percent of primary energy demand (%)



- Global natural gas demand grows by about 40 percent from 2016 to 2040
- The share of natural gas in the world's energy supply mix increases from 23 percent in 2016 to 26 percent in 2040
- Natural gas-rich regions like the Middle East and Russia/Caspian rely on natural gas to meet about half of their energy needs
- Abundant unconventional resources prompt North America's steady shift toward natural gas
- Natural gas plays an important role in fueling economic growth in Asia, Africa and Latin America



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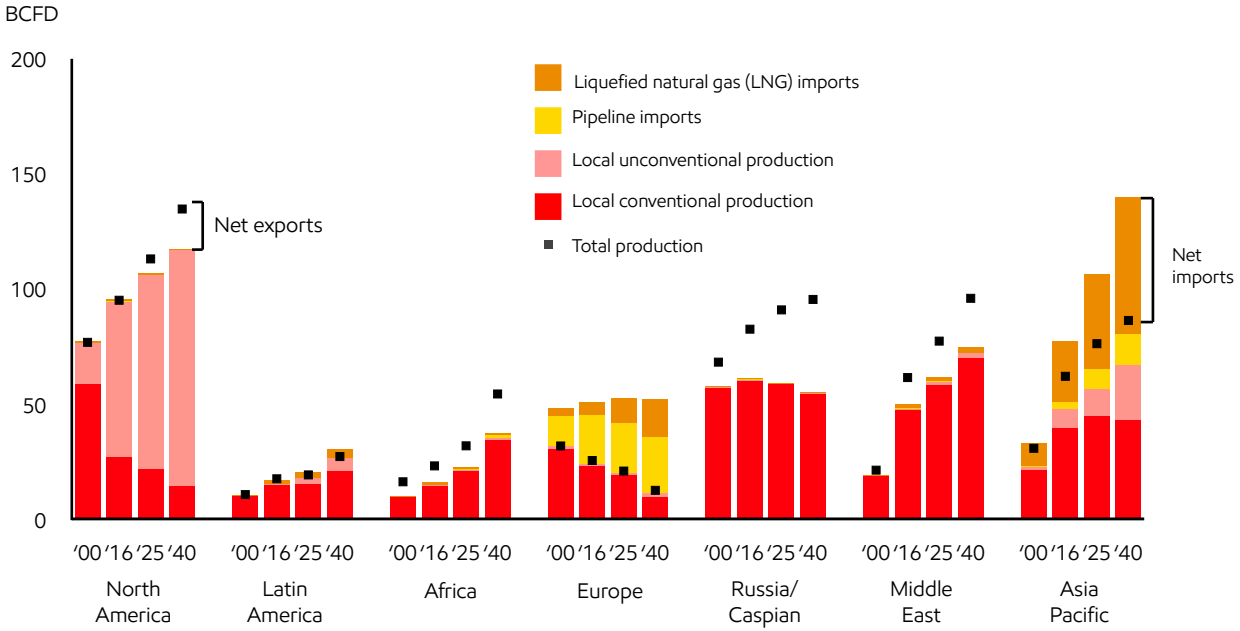
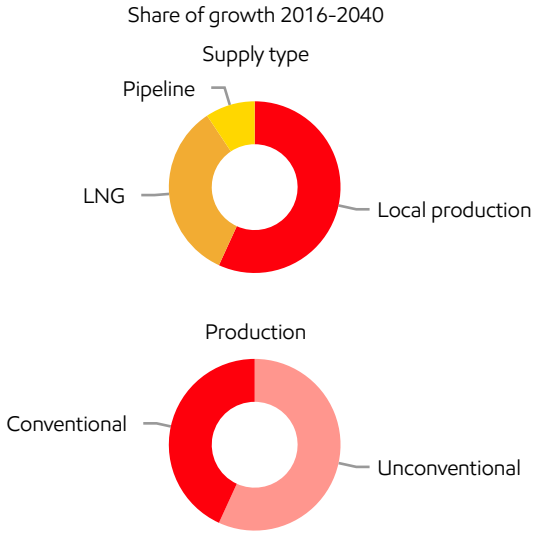
Supply

Natural gas – projections

Natural gas supply highlights regional diversity in meeting demand



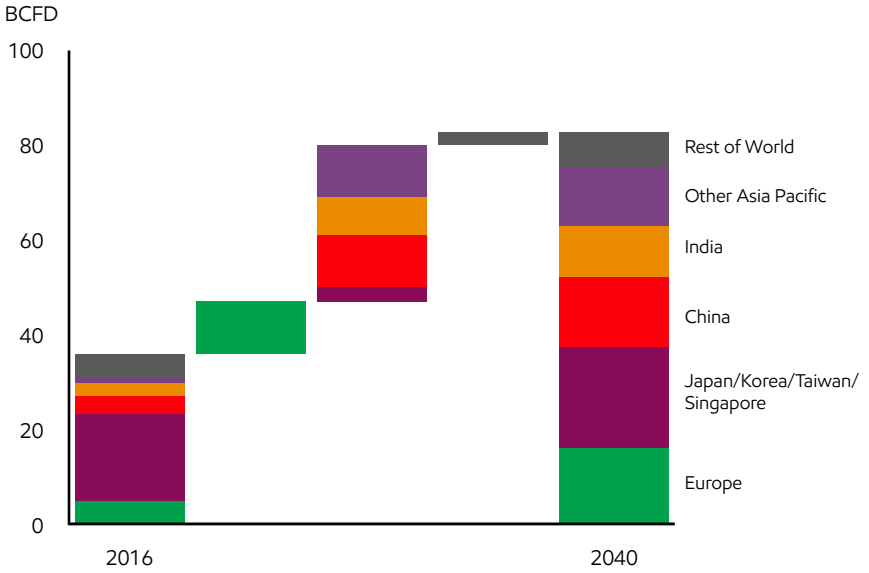


- Advances in unconventional gas production and liquefied natural gas markets continue to reshape natural gas supplies
- Abundant unconventional gas fuels regional demand growth and liquefied natural gas exports for North America
- Russia/Caspian remains a significant exporting region, supplying Europe and Asia Pacific via pipeline, while also expanding liquefied natural gas export capabilities
- The Middle East and Africa see rising demand and exports; Latin American demand outpaces supply growth
- Europe and Asia Pacific increasingly rely on natural gas trade to meet consumer needs, as local production falls short of demand

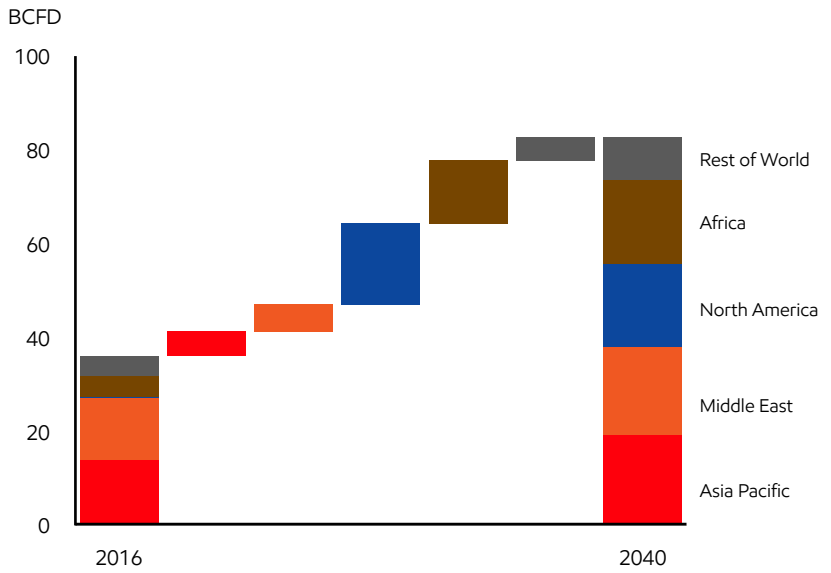
Supply

Natural gas – projections

Europe and Asia Pacific dominate LNG imports



Abundant natural gas supplies underpin new LNG exports



- Liquefied natural gas trade supplies one-third of natural gas demand growth from 2016 to 2040
- Together, Asia Pacific and Europe account for about 85 percent of liquefied natural gas imports in 2016 and 95 percent of the growth from 2016 to 2040
- Europe leverages competitive liquefied natural gas to diversify its natural gas import portfolio
- Air quality management is a key driver for China's and India's natural gas demand growth
- Other Asia Pacific importers utilize liquefied natural gas to fill existing natural gas infrastructure as domestic natural gas supplies plateau or decline

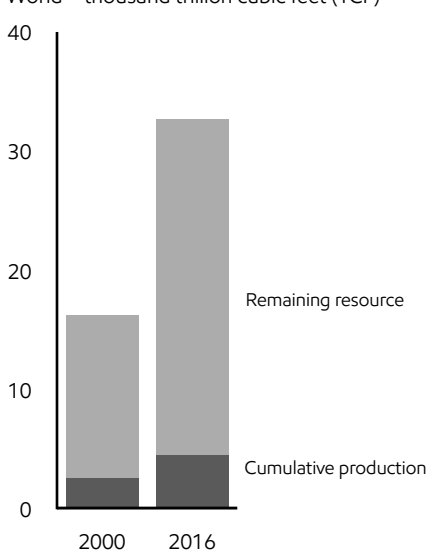
- Three-quarters of liquefied natural gas exports in 2016 originated in Asia Pacific or the Middle East
- By 2040, four regions will have similar liquefied natural gas exports: Asia Pacific, the Middle East, North America and Africa
- North America's exports grow the most as low-cost unconventional gas production prompts investment in liquefied natural gas
- Liquefied natural gas will remain highly competitive due to abundant natural gas resources and many aspiring exporters
- Low-cost liquefied natural gas supply sources will be advantaged in the marketplace

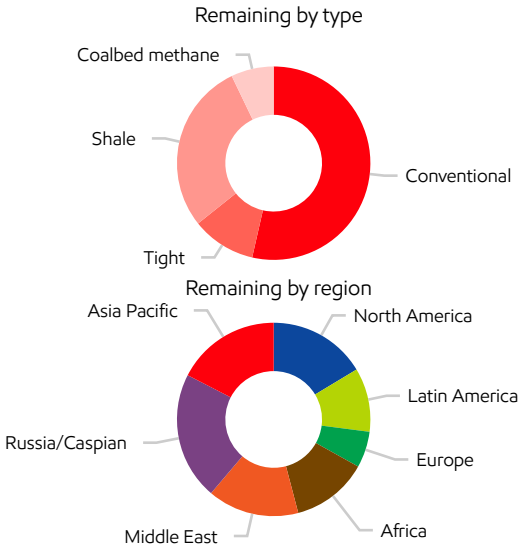
Supply

Natural gas – projections

Technology expands recoverable resources

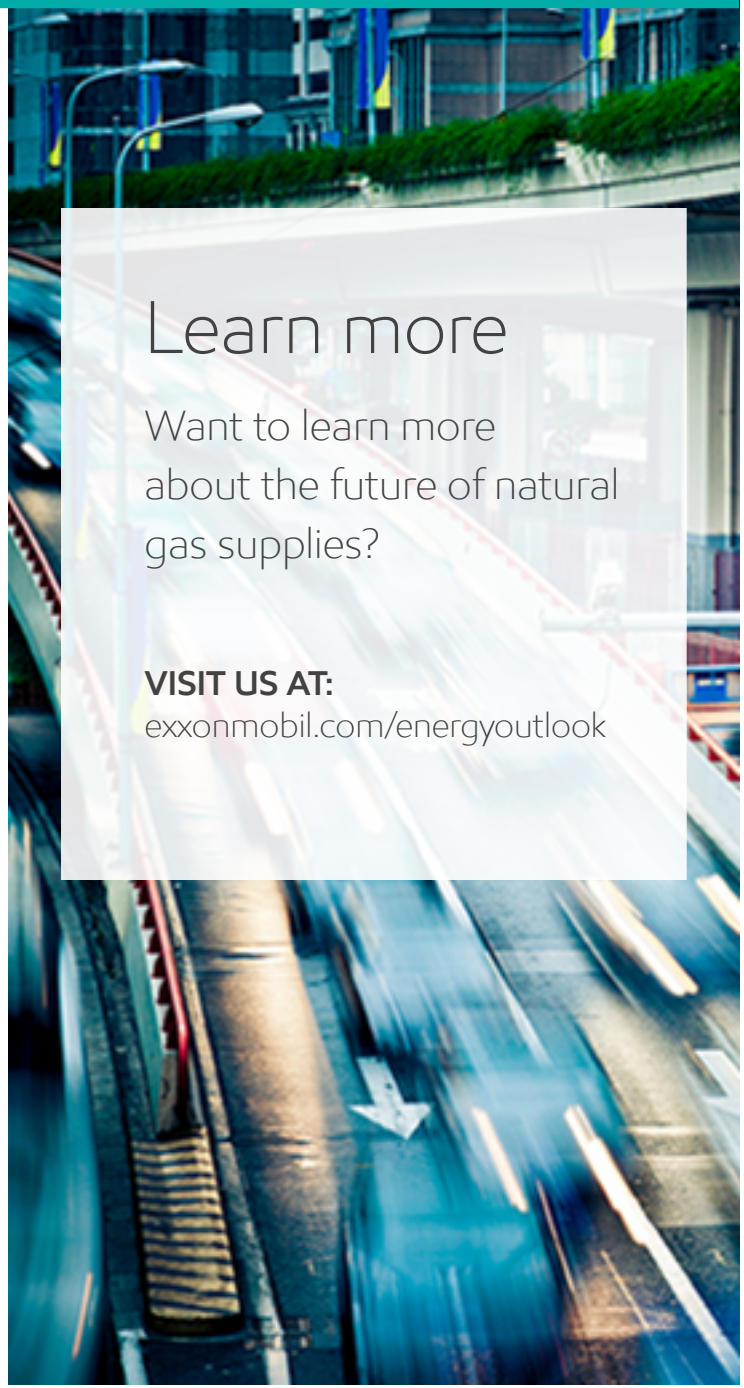
World – thousand trillion cubic feet (TCF)





Source: IEA

- Less than 15 percent of recoverable natural gas resources have been produced
- Remaining natural gas resources can provide more than 200 years of supply at current demand
- Natural gas resource estimates keep rising as technology unlocks resources previously considered too difficult or costly to produce
- About 45 percent of remaining natural gas resources are from unconventional sources like shale gas, tight gas and coal-bed methane
- Natural gas resources are geographically widespread



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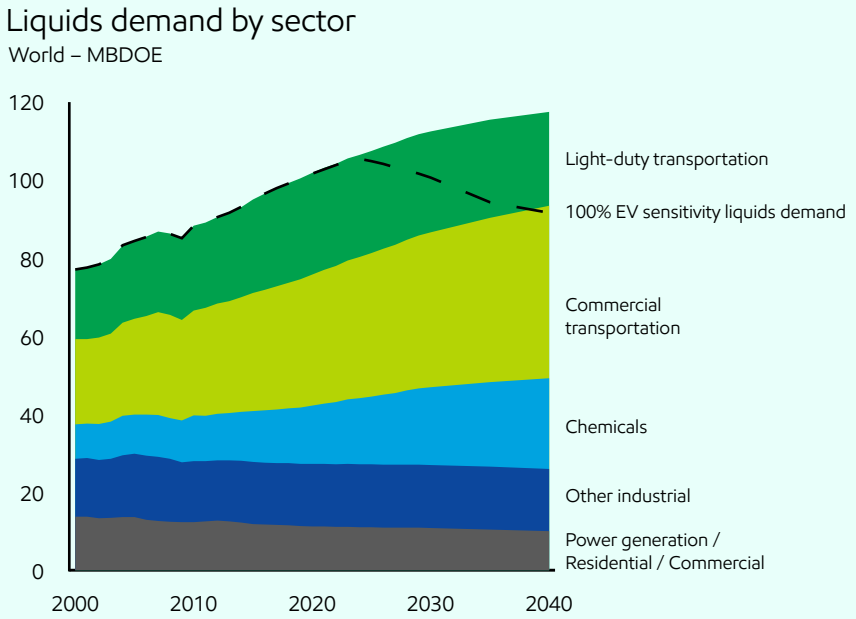
Test uncertainty

Demand for liquid fuels is projected to grow by about 20 percent through the *Outlook* period, driven primarily by commercial transportation and chemicals demand. Liquids demand from light-duty transportation peaks and declines with more efficient vehicles, even as personal mobility continues to rise.

Uncertainties in government policies and the pace of market penetration of various technologies could have a significant impact on light-duty transport sector demand. To assess the magnitude of this uncertainty, we developed a hypothetical sensitivity to illustrate the impact of all light-duty liquids demand being replaced by electricity by 2040.

To achieve this, global sales of light-duty vehicles would likely need to be 100 percent all-electric starting in 2025. This would require sales of about 110 million electric vehicles starting in 2025, rising to about 140 million in 2040 – more than 100 times the number of electric vehicles sold in 2016. Battery manufacturing capacity for electric cars would need to increase by more than 50 times from existing levels by 2025 under this hypothetical case.

Sensitivities – projections



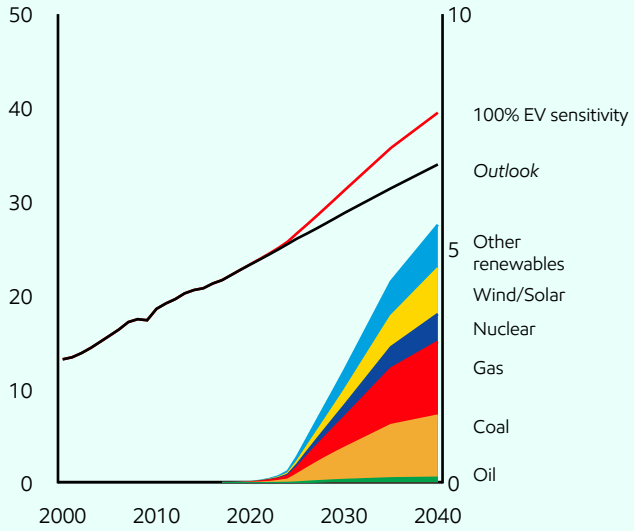
- In a 100 percent electric light-duty vehicles by 2040 sensitivity, light-duty transportation liquids demand would be fully displaced
- In this sensitivity, total liquids demand in 2040 could be similar to levels seen in 2013 as growth in chemicals and commercial transportation would mostly offset a decline in light-duty vehicle demand
- Post-2040, liquids demand would likely revert to modest growth as chemicals and commercial transportation demand continue to rise

Supply

Sensitivities – projections

Electricity demand

World – thousand TWh

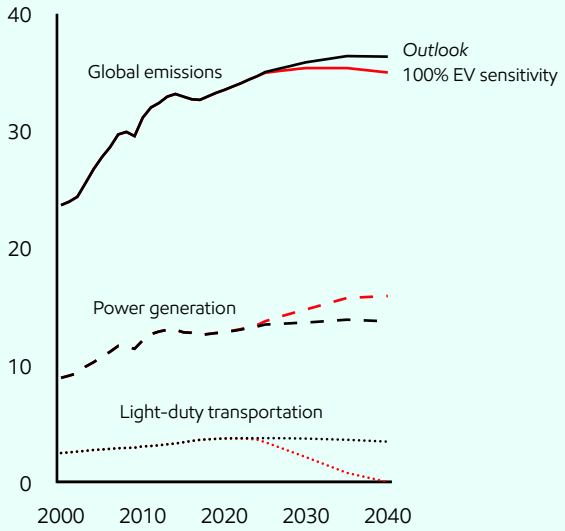


Demand increase

World – thousand TWh

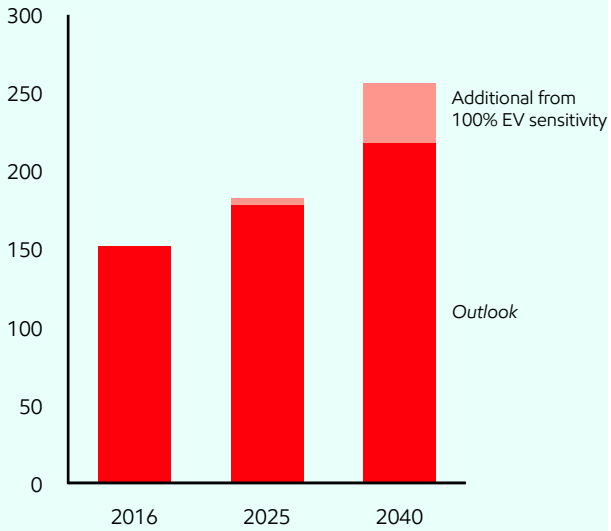
Energy-related CO_2 emissions

World – billion tonnes



Natural gas demand increases

World – gas into power generation - BCFD



- The additional electricity needed to power a 100 percent all-electric light-duty vehicle fleet could increase total electricity demand by about 15 percent in 2040 relative to the base *Outlook*
- Assuming the fuel mix for electricity generation is the same as in the *Outlook*, power generation from natural gas would be about 25 percent of the overall increase
- Under a 100 percent light-duty EV sensitivity, total energy-related CO_2 emissions in 2040 could be reduced by about 5 percent
- Light-duty tailpipe emissions would reduce to zero but emissions from power generation would rise with the increase in electricity demand
- CO_2 emissions from power generation could increase by about 15 percent, with coal accounting for 60 percent of the increase
- Higher electricity demand could lead to about a 20 percent increase in natural gas demand for power generation in 2040

Special Section

Pursuing a 2°C pathway

The climate challenge

Many uncertainties exist concerning the future of energy demand and supply, including potential actions that societies may take to address the risks of climate change. The following analysis is intended to provide a perspective on hypothetical 2°C scenarios.

Since 1992, when nations around the world established the United Nations Framework Convention on Climate Change (UNFCCC), there has been an international effort to understand and address the risks of climate change. After more than two decades of international effort, in December 2015, nations convened in Paris and drafted an agreement that for the first time signals that both developed and developing nations will strive to undertake action on climate change and report on related progress.

The Paris Agreement[1] "aims to strengthen the global response to the threat of climate change... by: Holding the increase in the global average temperature to well below 2°C above pre-industrial levels..."

Key elements of the agreement include:

- "Each party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve."
- "Each party shall communicate nationally determined contributions every five years."

The nationally determined contributions (NDCs) provide important signals on government expectations related to the general direction and pace of likely policy initiatives to address climate risks.[4] In this regard, the UNFCCC reported in May 2016 that "the estimated aggregate greenhouse gas emission levels in 2025 and 2030 resulting from the intended nationally determined contributions do not fall within the least-cost 2°C scenarios."[5,6]

The climate challenge –
Considering 2°C scenarios

According to the International Energy Agency (IEA), setting upon a "well below 2°C" pathway in concert with the Paris Agreement implies "comprehensive, systematic, immediate and ubiquitous implementation of strict energy and material efficiency measures."[7] Given a wide range of uncertainties, no single pathway can be reasonably predicted. As a result, many governments, universities and non-governmental organizations are seeking to analyze potential 2°C scenarios or pathways. Such studies may be useful in helping identify options to address climate risks and ensure energy remains reliable and affordable.

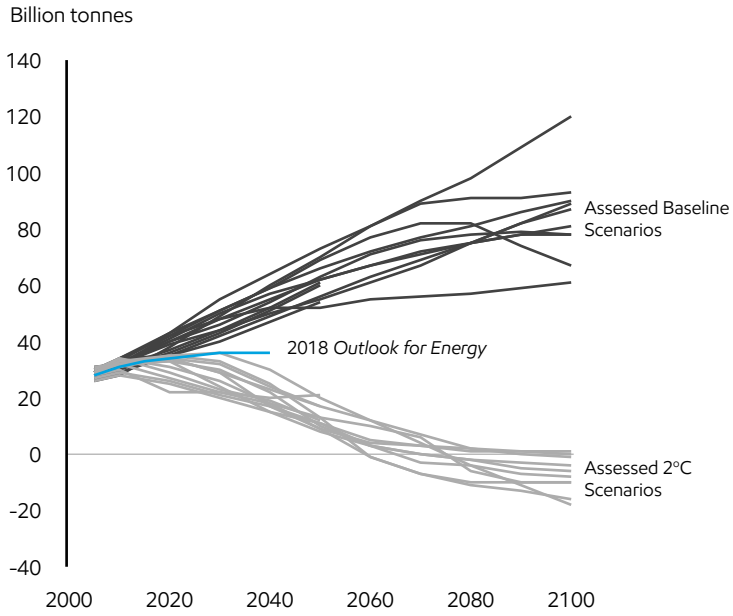
A key uncertainty relates to advances in technology that may influence the cost and potential availability of certain pathways toward a 2°C scenario. Many potential pathways are designed to utilize a full range of technology options, which may have significant benefits for society by minimizing related costs of a dramatic transition process.

Considerable work has been done in the scientific community to explore energy transformation pathways. A recent multi-model study coordinated by the Energy Modeling Forum at Stanford University (EMF 27) brought together many energy-economic models to assess technology and policy pathways associated with various climate stabilization targets (e.g., 450, 550 ppm CO_2 equivalent or CO_2e), partially in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

The chart to the right illustrates potential CO_2 emission trajectories under EMF 27 full technology scenarios[8] targeting a 2°C pathway (Assessed 2°C Scenarios) relative to the 2018 *Outlook*, and baseline pathways (Assessed Baseline Scenarios) with essentially no policy evolution beyond 2010. The 2018 *Outlook* incorporates significant efficiency gains and changes in the energy mix, resulting in a projected CO_2 emissions trajectory that resides between the pathways illustrated by the baseline and 2°C scenarios.

A key characteristic of the Assessed 2°C Scenarios is that energy-related CO_2 emissions go to zero, or potentially negative, by the end of the century. As shown, the 2°C pathways represent a stark and fairly rapid transition from the baseline scenarios, while also illustrating significantly different emission trajectories toward a 2°C ambition.

Global energy-related CO_2 emissions



Assessed scenarios include CO_2 emissions from energy and industrial processes

Many experts developed scenarios to reduce global CO_2 emissions consistent with an atmospheric GHG concentration (450 ppm CO_2e in 2100) consistent with a 2°C pathway. The chart above shows indicative pathways based on results of 13 models.

The climate challenge –
Considering 2°C scenarios (continued)

It is generally accepted that population and world economies will continue to grow, and that measures to address the risks of climate change should accommodate these factors. Therefore, across any reasonable range of pathways, two other factors remain critical to limiting CO_2 emissions:

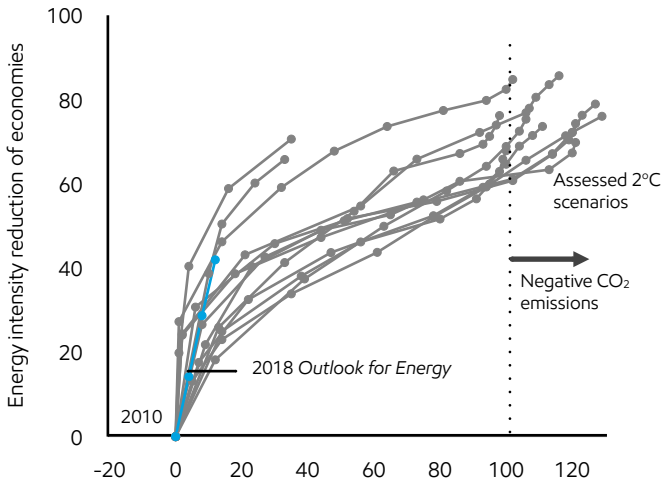
1. Reducing the energy intensity of economies (i.e., being more energy efficient), and

2. Reducing the CO_2 emissions intensity of the global energy mix.

In this regard, the adjacent chart illustrates the gains expected for both parameters under the Assessed 2°C Scenarios from 2010 to 2100, along with ExxonMobil's 2018 *Outlook* for 2010 to 2040. The *Outlook* projects progress on both parameters to 2040, with generally greater progress on energy intensity gains compared to the other pathways.

Energy and CO_2 emissions intensity pathways

World - percent change from 2010-2100 - ten year increments



EMF27-FT cases include CO_2 emissions from energy and industrial processes

These pathways imply that two things must happen. First, countries need to be more efficient in how they use energy (left axis)... and second, they need to use energies or technologies that reduce CO_2 emissions for every unit of energy they use (bottom axis).

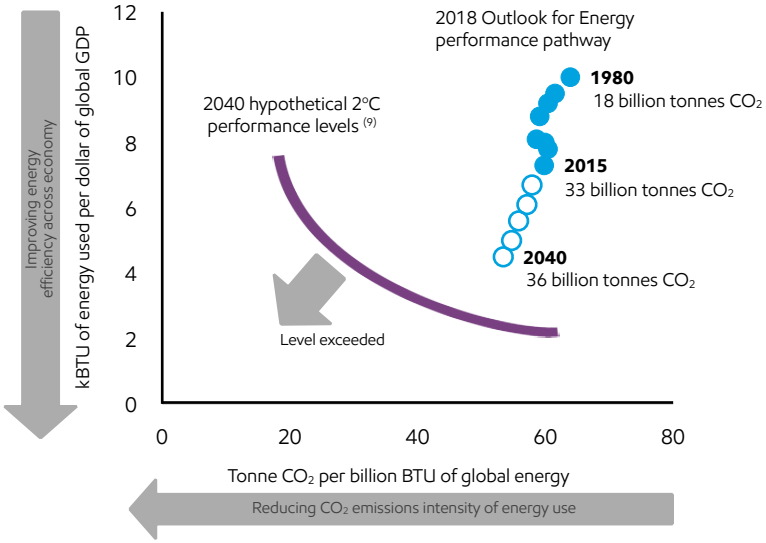
The climate challenge –
Considering 2°C scenarios (continued)

The chart to the right helps provide some historical context for the projected progress on these important parameters from 1980 through 2040 based on the 2018 *Outlook*. From 1980 to 2015, progress to slow the growth in energy-related CO_2 emissions was made primarily through energy efficiency gains. Despite those gains over 35 years, emissions rose from about 18 billion tonnes to about 33 billion tonnes. From 2015 to 2040, further gains in efficiency and CO_2 emissions intensity will be significant, helping slow global energy-related CO_2 emissions so that they will likely peak before 2040. However, they are projected to be twice the level of 1980 and about 10 percent above the 2016 level in 2040.

The chart also illustrates a range of 2040 "performance levels" reflecting hypothetical combinations of global energy intensity and CO_2 emission intensity levels that, if reached in 2040, might indicate the world was on a 2°C pathway. Even with the significant progress on energy and CO_2 emissions intensities envisioned by 2040 in the 2018 *Outlook*, it is estimated that there remains a significant gap to reach performance levels in 2040 that are indicative of 2°C pathway.

In summary, transitioning toward a 2°C pathway, as suggested by the range of related 2040 performance levels shown on the chart, would imply that global emissions peak and steadily fall to close to 1980 levels by 2040. This is daunting, considering the global population may be twice as large, and the world's economy may be five times as large by 2040 versus 1980 levels.

World energy-related CO_2 emissions relative to energy intensity and CO_2 emissions intensity



This chart shows global energy intensity (left axis) and CO_2 emissions intensity (bottom axis).

From 1980 to 2015, there were large gains in efficiency, though energy-related CO_2 emissions rose from 18 to 33 billion tonnes. The blue circle shown for 2040 indicates these emissions are projected to be about 36 billion tonnes even with significant gains in efficiency and CO_2 emissions intensity.

To be on a 450 ppm, or hypothetical 2°C, pathway, the performance in 2040 likely needs to be significantly closer to the purple line, implying faster gains in efficiency and/or faster reductions in CO_2 emissions per unit of energy. This would increase the chance of reaching a 2°C pathway, with further gains required between 2040 and 2100.

The climate challenge –
Key takeaways considering 2°C scenarios

The review of the Assessed 2°C Scenarios relative to the 2018 *Outlook* suggest several key takeaways:

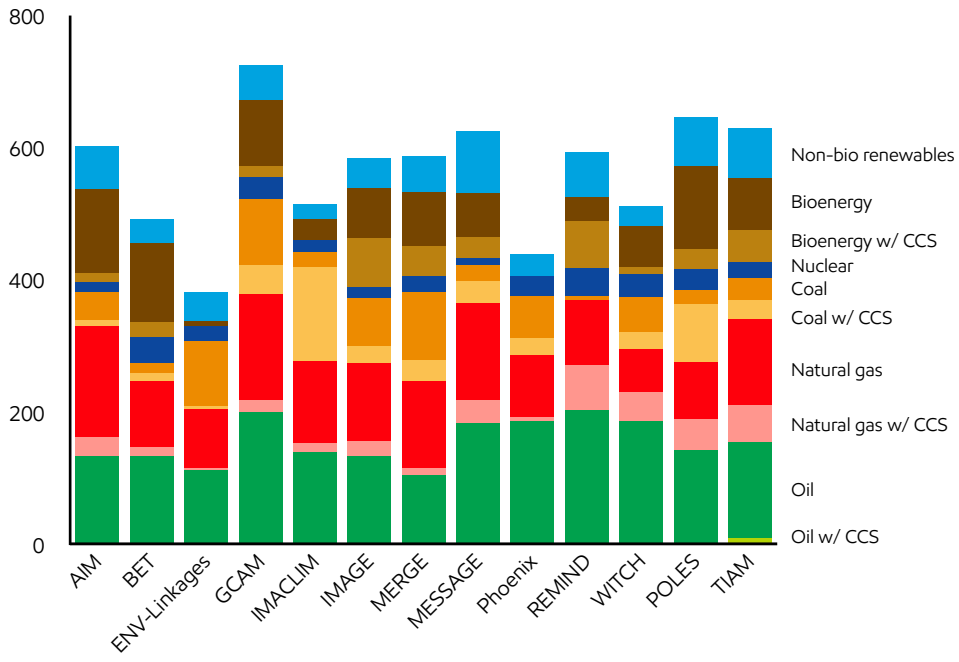
- To quickly reduce global GHG emissions (including CO_2) toward a 2°C pathway, much more stringent policy interventions, with restrictive impacts on economic and human activities, will be needed.

- Reducing the CO_2 emissions intensity of the world's energy mix remains challenging; the Assessed 2°C Scenarios generally include significant reductions in coal and growing utilization of carbon capture and storage (CCS) technologies for coal, natural gas and bioenergy. The cost-effective availability and deployment of many different technologies is likely to be critical to ensure reliable, affordable energy while also moving toward a 2°C pathway.

- To close the gap, and barring a reduction in projected GDP, much faster improvements in energy intensity and/or CO_2 emissions intensity are required to achieve a 2°C pathway. As the chart at the right illustrates, the Assessed 2°C Scenarios suggest that predicting absolute 2040 energy demand levels in total and by energy type carries significant uncertainty, and further suggest that scenario outcomes may be heavily influenced by technology and policy assumptions.

2040 global demand by model by energy type in the Assessed 2°C Scenarios

Exajoules



The climate challenge –

Potential energy implications considering 2°C scenarios

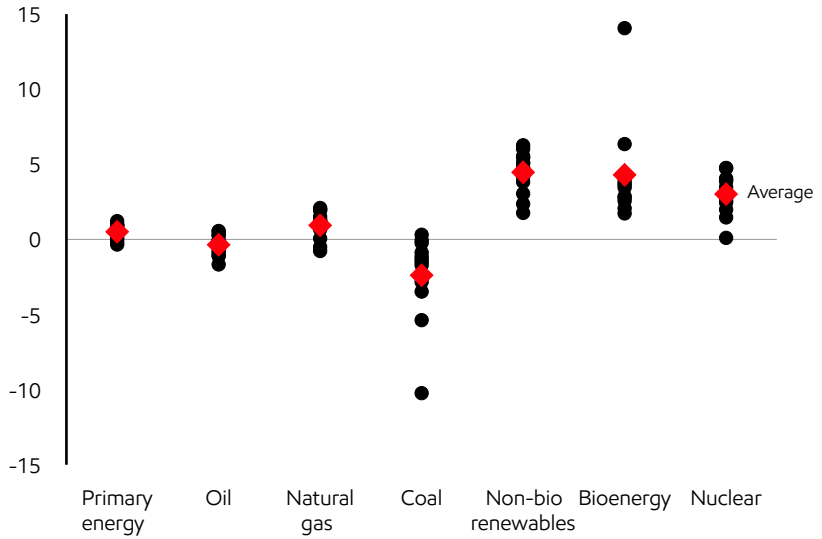
The Assessed 2°C Scenarios produce a variety of views on the potential impacts on global energy demand in total and by specific types of energy, with a range of possible growth rates for each type of energy (adjacent chart). Since it is impossible to know which elements, if any, of these models are correct, we used an average of all 13 scenarios to approximate growth rates for the various energy types as a means to estimate trends to 2040 indicative of hypothetical 2°C pathways.

On a worldwide basis, based on the average of the Assessed 2°C Scenarios' growth rates, primary energy demand is projected to increase about 0.5 percent per year on average from 2010 to 2040. Expected changes in demand vary by energy type by model. Based on the average of the growth rates:

- Oil demand is generally projected to decline about 0.4 percent per year.
- Natural gas demand is expected to increase about 0.9 percent per year.
- The outlook for coal is the most negative, with diverse projections showing an average decline of about 2.4 percent per year, or about a 50 percent decline by 2040.
- The average annual growth rates for renewable energies and nuclear are generally quite strong, averaging between 4 and 4.5 percent for non-bioenergy (e.g., hydro, wind, solar) and bioenergy, and about 3 percent for nuclear.

Ranges of predicted changes in global demand in Assessed 2°C Scenarios

13 models - Average annual growth rates in percent, 2010-2040



This chart illustrates model results of the 13 scenarios showing how energy demand is projected to grow or decline by energy type through 2040.

All energy sources remain important across all 13 scenarios though the mix of energy and technology shifts over time. Oil and natural gas remain important energy types across all 13 scenarios. Oil demand is projected to decline modestly on average, and much more slowly than its natural rate of decline from existing fields. Natural gas demand is projected to grow on average due to its many advantages.

The climate challenge –
Potential investment implications

Using the growth rates from the Assessed 2°C Scenarios and a standard baseline for 2010 demand, oil demand is estimated to decline on average from about 95 million barrels per day in 2016 to about 78 million barrels per day in 2040. Estimated demand based on the low and high growth rates ranges from about 53 to 103 million barrels per day in 2040.

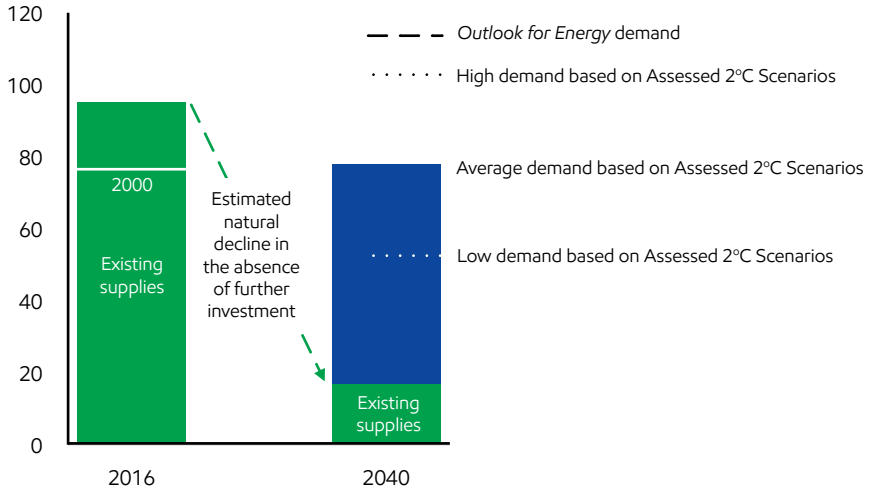
Using the same approach for natural gas, demand is estimated to increase on average to about 445 billion cubic feet per day in 2040. Based on the low and high end growth rates, estimated demands ranges from about 265 to 625 billion cubic feet per day in 2040.

Significant investments will be needed in the upstream sector to meet global demand for oil and natural gas. This reflects the fact that natural declines in production from existing fields are higher than a decline in demand, such as is envisioned for oil on average in the Assessed 2°C Scenarios. A large portion of the investments would be needed simply to compensate for the declines at existing fields.

The International Energy Agency, in its New Policies Scenario, estimates cumulative oil and natural gas investment may reach approximately $21 trillion between 2017 and 2040, including about $15 trillion in the upstream sector, with about $10 trillion in the upstream oil sector.

Global liquids supply estimates

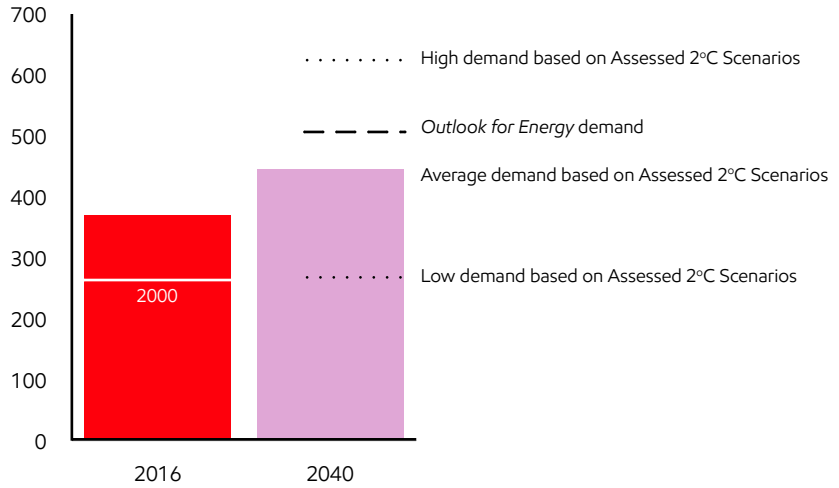
MBDOE



Excludes biofuels

Global natural gas supply estimates

BCFD



The climate challenge –
Seeking practical solutions

Billions of people still lack access to modern energy and technology as they struggle to improve their living standards and reduce the negative health impacts of energy poverty, while billions of others enjoy the conveniences of modern life. Awareness of this enduring disparity is a reminder of the need to expand access to reliable, affordable energy for all, even as parties around the world pursue common ambitions to improve the environment and address the risks of climate change.

Effectively managing the risks of climate change will require practical, cost-effective solutions. Opportunities exist worldwide across all sectors to improve efficiency and reduce energy-related emissions. As noted earlier, these solutions are expected to focus on improving energy intensity or efficiency of economies, as well as reducing the carbon intensity of the world's energy mix.

Boosting energy efficiency

To pursue a 2°C pathway to address the risks of climate change, the need for efficiency gains is likely to ramp up significantly, meaning that capturing the most cost-effective efficiency gains will become even more important in order to spare society an unnecessary economic burden associated with high-cost options to reduce emissions.

Boosting efficiency while meeting essential needs for products and services and supporting standard of living improvements will require effective investments and sound policies to promote them. Opportunities to boost efficiency are many and varied, ranging from better equipment (e.g., transportation vehicles, appliances) to electrical distribution networks to better insulation in buildings. Gains are also likely in systems affecting how people live or how businesses operate. Importantly, not all of the same mechanisms apply across all energy sectors.

Shifting the energy mix

Shifting the CO_2 emissions intensity of the energy mix to lower levels, while keeping energy reliable and affordable, also requires investment, with an eye toward opportunities for using less carbon-intensive energy sources to meet needs across the range of demand sectors. For example, while bioenergy could be used across all sectors, nuclear energy is limited to the power generation segment.

The table to the right highlights a likely distribution of technologies and other efforts across various energy demand sectors to boost efficiency and lower the CO_2 emissions intensity of energy use.

	Energy Demand Sectors			
Pathway levers	Power	Transport	Industry	Buildings
Energy intensity				
Equipment/ Operations	x	x	x	x
Materials		x	x	x
Retrofits				x
Lifestyle choices		x		x
Carbon intensity				
Bioenergy	x	x	x	x
Hydro	x			
Geothermal	x			x
Nuclear	x			
Solar	x			x
Wind	x			
Electrification		x	x	x
Natural gas	x	x	x	x
CCS	x		x	

The climate challenge –
Seeking practical solutions (continued)

Adopting policies to promote cost-effective solutions

To help speed the application of practical and cost-effective solutions across the entire energy system, open and informed discussions will help clarify the potential and relative value of available options. Further, policy frameworks that promote better transparency on the costs and benefits of various options and rely on market-based solutions should be pursued. As the IEA has noted, clear price signals have advantages, including that "higher prices stimulate consumers to reconsider their energy consumption and make savings where this can be done most cheaply, whereas regulation through mandatory standards may not be the least-cost or most effective approach." [10]

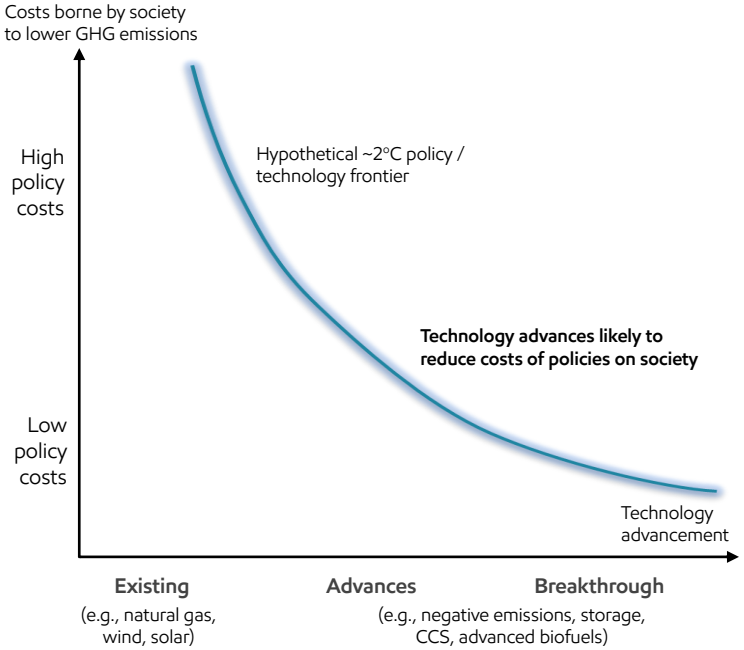
The long-term nature of the climate challenge promises an evolution of available solutions. Therefore, policies that promote innovation and flexibility afforded by competition and free markets will be critical to ensuring the world pursues the most cost-effective opportunities.

Investing in research and development to advance technology

Ongoing research and development to spark technological advances will also be important to help minimize the costs of reducing emissions. This will preserve limited financial resources for other needs, including helping to ensure universal access to reliable and affordable energy.

Advancing the application of cost-effective technology solutions around the world will likely be critical to pursue a 2°C pathway, while helping keep energy reliable and affordable for an expanding population. As the chart to the right shows, expanding technology options through ongoing research and development efforts remains important to accelerate the options that can play a role in meeting people's energy needs while reducing the risks of climate change. Such technologies include those related to carbon capture and storage (CCS), advanced biofuels and battery technology. Without robust development of such technology options, the stringency of policies and their related costs to society will prove more burdensome.

Technology key to reducing societal costs of 2°C pathway



Policy / Technology matrix is illustrative only

Technology advances are expected to lower the cost to consumers and taxpayers of reducing GHG emissions like CO_2.

The climate challenge –
Seeking practical solutions (continued)

Keeping options open

Transformation of the world's energy system as envisioned by a 2°C scenario is unprecedented. Therefore, it is understandable that governments, businesses and individuals exercise care in weighing its potential implications. A key consideration is the significant value for society in not prematurely foreclosing options or negating reliable, affordable and practical energy systems that billions of people depend upon.

Practical solutions to the world's energy and climate challenges will benefit from market competition as well as well-informed, well-designed and transparent policy approaches that carefully weigh costs and benefits. Such policies are likely to help manage the risks of climate change while also enabling societies to pursue other high priority goals around the world – including clean air and water, access to reliable, affordable energy, and economic progress for all people.

[1] http://unfccc.int/paris_agreement/items/9485.php

[2] EMF was established at Stanford in 1976 to bring together leading experts and decisionmakers from government, industry, universities, and other research organizations to study important energy and environmental issues. For each study, the Forum organizes a working group to develop the study design, analyze and compare each model's results and discuss key conclusions. https://emf.stanford.edu/about. EMF is supported by grants from the U.S. Department of Energy, the U.S. Environmental Protection Agency as well as industry affiliates including ExxonMobil. https://emf.stanford.edu/industry-affiliates

[3] Energy demand as used in this Outlook refers to commercial and non-commercial energy (e.g., traditional biomass) consumed as a fuel or used as a feedstock for the production of chemicals, asphalt, lubricants, waxes and other specialty products. Coal demand includes metallurgical coal. Gas demand includes flared gas. To avoid double counting, derived liquids (e.g., from gas-to-liquids) and synthetic gas (e.g., from coal-to-gas) are only accounted for in their final form (i.e., liquid or gas) and not in the energy type from which they were derived (i.e., gas or coal). The fuel and loss involved in the conversion process is accounted for in the energy industry sub-sector.

[4] Taking action to address climate change and its impacts is also one of the United Nations' 17 Sustainable Development Goals.

[5] UNFCCC, *Aggregate effect of the intended nationally determined contributions: an update*, page 12, http://unfccc.int/focus/indc_portal/ items/9240.php

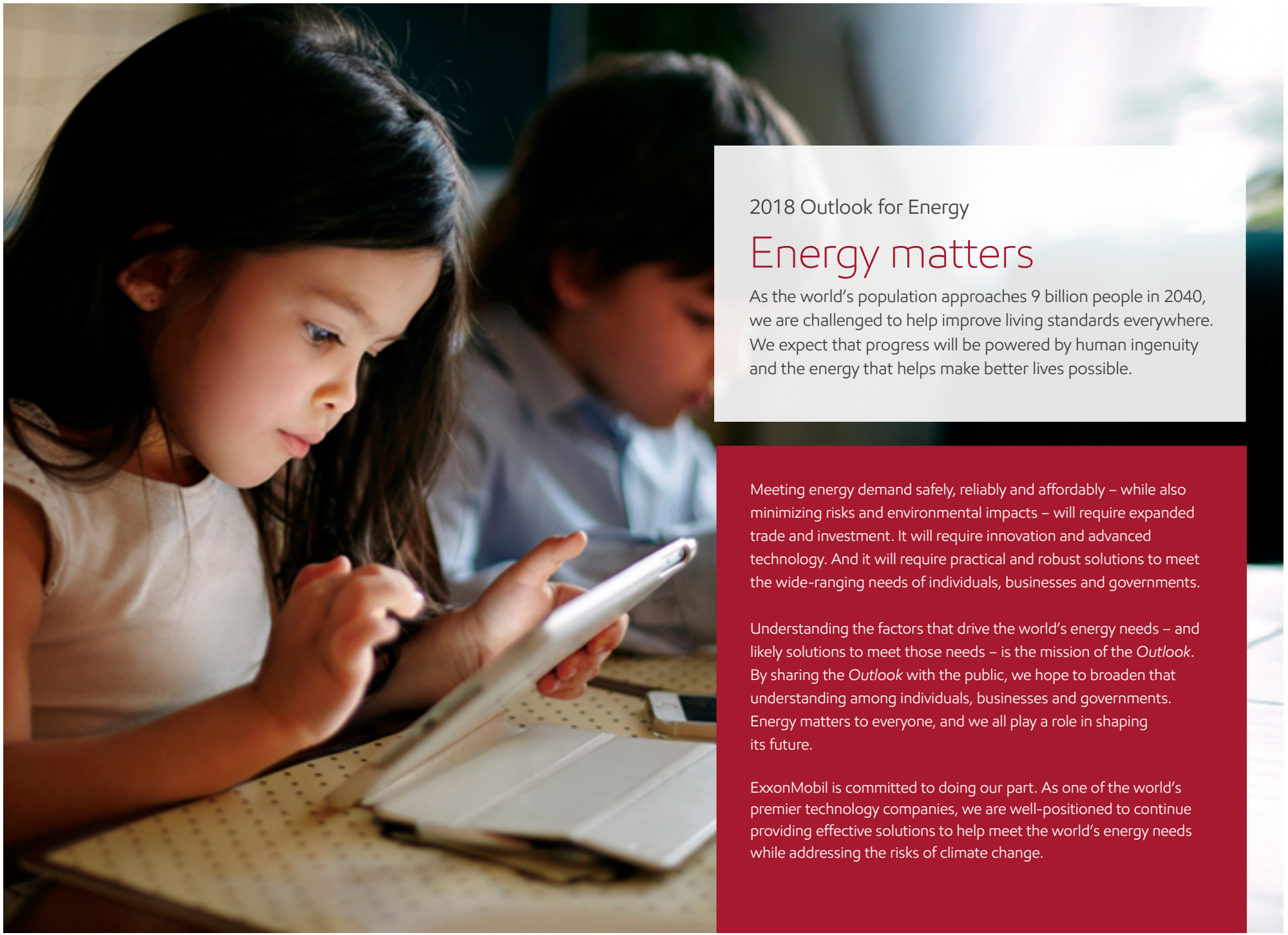
[6] Ibid, page 10: "Compared with global emission levels in 1990, 2000 and 2010, global aggregate emission levels resulting from the INDCs are expected to be higher by: 40 (33-47) per cent in 2025 and 44 (34-53) per cent in 2030 in relation to the global emission level in 1990; 35 (28-41) per cent in 2025 and 38 (29-47) per cent in 2030 in relation to the global emission level in 2000; and 13 (7-19) per cent in 2025 and 16 (8-23) per cent in 2030 in relation to the global emission level in 2010."

[7] IEA, *Perspectives for the Energy Transition*, page 57

[8] To understand some of the characteristics of future transition pathways, we analyzed energy and emissions data from a range of EMF27 stabilization, policy and technology targets, primarily focusing on 450 and 550 stabilization targets, as well as no policy cases that utilize a full suite of technologies. The suite of full technologies (FT) includes a range of options, including: energy efficiency, nuclear, carbon capture and storage (CCS), biofuels and non-bio renewables such as solar and wind. The EMF27 study considered other technology-limited scenarios, but a key finding was that the unavailability of carbon capture and storage and limited availability of bioenergy had a large impact on feasibility and cost. Given the potential advantages to society of utilizing all available technology options, we focused on capturing the results of different EMF27 models that ran 450-FT cases; we were able to download data for 13 such scenarios, and utilized that data as provided for analysis purposes (most of the scenarios had projections extending to 2100). Data downloaded from: https://secure.iiasa.ac.at/web-apps/ene/AR5DB

[9] Based on average Assessed 2°C Scenarios CO_2 emissions (~20 billion tonnes including energy and industrial processes); ExxonMobil GDP assumptions consistent with 2018 Outlook.

[10] IEA, *World Energy Outlook 2016*, page 290



2018 Outlook for Energy

Energy matters

As the world's population approaches 9 billion people in 2040, we are challenged to help improve living standards everywhere. We expect that progress will be powered by human ingenuity and the energy that helps make better lives possible.

Meeting energy demand safely, reliably and affordably – while also minimizing risks and environmental impacts – will require expanded trade and investment. It will require innovation and advanced technology. And it will require practical and robust solutions to meet the wide-ranging needs of individuals, businesses and governments.

Understanding the factors that drive the world's energy needs – and likely solutions to meet those needs – is the mission of the *Outlook*. By sharing the *Outlook* with the public, we hope to broaden that understanding among individuals, businesses and governments. Energy matters to everyone, and we all play a role in shaping its future.

ExxonMobil is committed to doing our part. As one of the world's premier technology companies, we are well-positioned to continue providing effective solutions to help meet the world's energy needs while addressing the risks of climate change.

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
									2016	2016		
Regions	2000	2010	2016	2020	2025	2030	2035	2040	2040	2040	2016	2040
World	404	515	552	579	613	643	665	681	0.9%	23%	100%	100%
OECD	218	224	218	219	220	219	216	212	(0.1)%	(3)%	39%	31%
Non-OECD	186	292	334	360	394	423	449	469	1.4%	40%	61%	69%
Africa	22	29	33	37	42	47	53	59	2.4%	77%	6%	9%
Asia Pacific	123	202	231	250	273	290	305	315	1.3%	36%	42%	46%
China	46	102	118	125	135	141	146	147	0.9%	25%	21%	22%
India	18	27	36	41	49	56	61	66	2.6%	85%	6%	10%
Europe	77	80	75	75	73	72	70	68	(0.4)%	(9)%	14%	10%
European Union	71	72	67	66	64	62	60	58	(0.6)%	(14)%	12%	8%
Latin America	19	25	28	30	32	34	37	40	1.5%	42%	5%	6%
Middle East	17	28	34	37	40	44	46	48	1.4%	40%	6%	7%
North America	110	109	109	110	112	114	113	111	0.1%	3%	20%	16%
United States	93	91	89	90	91	92	91	89	—%	—%	16%	13%
Russia/Caspian	37	42	41	41	41	41	40	40	(0.2)%	(4)%	8%	6%
Energy by type - World												
Primary	404	515	552	579	613	643	665	681	0.9%	23%	100%	100%
Oil	145	164	177	186	195	203	208	211	0.7%	19%	32%	31%
Natural gas	89	116	127	137	149	160	168	175	1.3%	38%	23%	26%
Coal	91	140	141	139	143	141	141	138	(0.1)%	(2)%	25%	20%
Nuclear	27	29	27	31	33	38	42	46	2.3%	72%	5%	7%
Biomass/waste	40	49	54	56	57	57	57	57	0.2%	5%	10%	8%
Hydro	9	12	14	15	16	17	18	19	1.3%	35%	2%	3%
Other renewables	3	7	12	16	21	26	30	36	4.6%	195%	2%	5%
End-use sectors - World												
Residential and commercial												
Total	96	112	116	122	129	134	139	143	0.8%	22%	100%	100%
Oil	13	12	11	11	11	10	10	10	(0.6)%	(13)%	10%	7%
Natural gas	21	24	24	25	26	27	28	28	0.7%	18%	20%	20%
Biomass/waste	29	33	35	35	36	35	35	33	(0.1)%	(4)%	30%	23%
Electricity	23	32	36	40	45	50	55	61	2.2%	70%	31%	42%
Other	10	11	11	11	11	11	11	11	(0.2)%	(4)%	10%	8%
Transportation												
Total	77	95	109	118	126	132	137	141	1.1%	29%	100%	100%
Oil	75	91	103	111	117	121	124	126	0.8%	22%	95%	89%
Biofuels	0	2	3	4	4	5	5	6	2.5%	80%	3%	4%
Natural gas	0	1	2	3	3	4	5	7	6.2%	321%	1%	5%
Other	1	1	1	1	1	2	2	3	4.2%	167%	1%	2%
Industrial												
Total	143	193	205	213	226	237	245	250	0.8%	22%	100%	100%
Oil	44	50	53	55	59	63	66	68	1.1%	29%	26%	27%
Natural gas	37	45	50	53	57	61	63	65	1.2%	32%	24%	26%
Coal	26	49	47	47	47	47	46	44	(0.3)%	(7)%	23%	18%
Electricity	22	31	36	39	43	46	50	53	1.6%	46%	18%	21%
Other	14	18	19	19	19	20	20	20	0.2%	5%	9%	8%
Power generation - World												
Primary	145	191	207	217	234	248	262	273	1.2%	32%	100%	100%
Oil	13	11	10	9	8	8	8	7	(1.4)%	(29)%	5%	3%
Natural gas	31	46	52	56	62	67	72	75	1.5%	43%	25%	27%
Coal	61	86	89	88	92	91	93	91	0.1%	2%	43%	33%
Nuclear	27	29	27	31	33	38	42	46	2.3%	72%	13%	17%
Hydro	9	12	14	15	16	17	18	19	1.3%	35%	7%	7%
Wind	0	1	3	5	7	9	11	13	6.0%	308%	2%	5%
Other renewables	4	7	11	13	15	18	20	22	2.9%	98%	5%	8%
Electricity demand (terawatt hours)												
World	13225	18597	21300	23319	26095	28793	31444	33985	2.0%	60%	100%	100%
OECD	8609	9715	9676	10056	10546	11030	11367	11630	0.8%	20%	45%	34%
Non-OECD	4616	8882	11624	13263	15549	17763	20077	22355	2.8%	92%	55%	66%

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
OECD									2016	2016		
Energy by type	**2000**	**2010**	**2016**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2016**	**2040**
Primary	218	224	218	219	220	219	216	212	(0.1)%	(3)%	100%	100%
Oil	91	86	85	84	83	81	79	76	(0.5)%	(10)%	39%	36%
Natural gas	47	55	58	60	63	66	67	67	0.6%	16%	27%	32%
Coal	43	42	34	31	27	23	20	17	(2.9)%	(51)%	15%	8%
Nuclear	23	24	20	21	21	21	22	22	0.3%	7%	9%	10%
Biomass/waste	7	9	10	10	10	10	10	10	0.1%	2%	5%	5%
Hydro	5	5	5	5	5	5	5	6	0.6%	15%	2%	3%
Other renewables	2	4	7	9	11	12	14	15	3.5%	126%	3%	7%
End-use sectors												
Residential and commercial												
Total	46	50	46	46	46	46	45	45	(0.1)%	(2)%	100%	100%
Oil	9	7	5	4	4	3	2	2	(3.8)%	(60)%	11%	4%
Natural gas	16	17	16	16	16	15	15	15	(0.2)%	(5)%	34%	33%
Biomass/waste	2	3	3	3	2	2	2	2	(0.9)%	(20)%	5%	5%
Electricity	17	21	21	21	22	23	24	24	0.7%	18%	45%	54%
Other	2	3	2	2	2	2	2	2	(0.9)%	(19)%	5%	4%
Transportation												
Total	52	54	57	57	57	57	57	55	(0.1)%	(2)%	100%	100%
Oil	51	52	54	54	54	53	52	50	(0.3)%	(8)%	95%	90%
Biofuels	0	2	2	2	2	3	3	3	1.4%	39%	4%	5%
Natural gas	0	0	0	0	1	1	1	2	10.6%	1022%	–%	3%
Other	0	0	0	0	0	1	1	1	4.1%	163%	1%	2%
Industrial												
Total	68	65	66	67	68	69	69	69	0.2%	4%	100%	100%
Oil	25	24	23	23	24	24	24	23	–%	–%	35%	34%
Natural gas	18	18	20	21	23	24	24	24	0.8%	20%	30%	34%
Coal	8	7	6	5	4	4	3	3	(3.8)%	(60)%	10%	4%
Electricity	12	12	12	12	13	14	14	14	0.8%	20%	18%	21%
Other	4	4	4	5	5	5	5	5	0.2%	5%	7%	7%
Power generation												
Primary	85	90	85	86	86	86	86	85	–%	–%	100%	100%
Oil	6	3	2	2	1	1	1	1	(4.6)%	(68)%	3%	1%
Natural gas	14	20	22	22	24	26	26	27	0.8%	20%	26%	32%
Coal	35	34	27	25	23	20	17	14	(2.7)%	(48)%	32%	16%
Nuclear	23	24	20	21	21	21	22	22	0.3%	7%	24%	25%
Hydro	5	5	5	5	5	5	5	6	0.6%	15%	6%	7%
Wind	0	1	2	3	4	5	6	7	5.0%	224%	2%	8%
Other renewables	3	4	6	7	8	8	9	9	1.6%	46%	8%	11%

General note on data tables: Rounding may lead to minor differences between totals and the sum of their individual parts.

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
Non-OECD									2016	2016		
Energy by type	**2000**	**2010**	**2016**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2016**	**2040**
Primary	186	292	334	360	394	423	449	469	1.4%	40%	100%	100%
Oil	55	78	93	102	112	122	129	135	1.6%	46%	28%	29%
Natural gas	41	61	70	77	86	94	101	108	1.9%	56%	21%	23%
Coal	48	98	107	108	116	118	121	121	0.5%	13%	32%	26%
Nuclear	4	5	7	9	12	17	21	24	5.6%	272%	2%	5%
Biomass/waste	33	40	44	46	46	47	47	47	0.2%	6%	13%	10%
Hydro	4	7	9	10	11	12	12	13	1.6%	45%	3%	3%
Other renewables	1	3	5	8	10	13	16	20	5.8%	284%	2%	4%
End-use sectors												
Residential and commercial												
Total	50	63	71	76	83	88	93	98	1.4%	38%	100%	100%
Oil	5	5	6	7	7	7	8	8	0.9%	25%	9%	8%
Natural gas	5	7	8	10	11	12	13	13	2.0%	62%	12%	14%
Biomass/waste	27	30	32	33	33	33	32	31	(0.1)%	(2)%	46%	32%
Electricity	6	11	15	18	23	27	32	36	3.7%	141%	21%	37%
Other	8	8	9	9	9	9	9	9	–%	–%	13%	9%
Transportation												
Total	25	41	52	60	68	75	81	86	2.1%	64%	100%	100%
Oil	24	39	49	56	63	68	72	76	1.8%	55%	94%	88%
Biofuels	0	1	1	1	2	2	3	3	3.9%	152%	2%	3%
Natural gas	0	1	1	2	3	3	4	5	5.3%	247%	3%	6%
Other	0	1	1	1	1	1	2	2	4.2%	169%	1%	2%
Industrial												
Total	76	127	139	146	157	168	176	182	1.1%	31%	100%	100%
Oil	19	26	30	32	35	39	42	45	1.7%	51%	21%	25%
Natural gas	19	27	30	32	35	38	40	42	1.4%	40%	21%	23%
Coal	18	42	41	42	43	44	43	42	0.1%	1%	30%	23%
Electricity	9	19	24	26	29	32	35	38	1.9%	59%	17%	21%
Other	10	13	14	15	15	15	15	15	0.2%	5%	10%	8%
Power generation												
Primary	60	101	122	131	148	162	176	189	1.8%	55%	100%	100%
Oil	7	8	8	7	7	7	7	6	(0.8)%	(18)%	6%	3%
Natural gas	17	26	30	33	38	41	45	48	2.0%	61%	25%	26%
Coal	26	52	62	63	69	71	76	77	0.9%	23%	51%	41%
Nuclear	4	5	7	9	12	17	21	24	5.6%	272%	5%	13%
Hydro	4	7	9	10	11	12	12	13	1.6%	45%	7%	7%
Wind	0	0	1	2	3	4	5	7	7.4%	461%	1%	3%
Other renewables	1	3	5	6	8	9	11	13	4.2%	167%	4%	7%

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
									2016	2016		
Regions	2000	2010	2016	2020	2025	2030	2035	2040	2040	2040	2016	2040
AFRICA												
Primary	22	29	33	37	42	47	53	59	2.4%	77%	100%	100%
Oil	5	7	8	9	11	12	14	16	3.1%	107%	23%	27%
Natural gas	4	5	6	6	8	9	11	13	3.5%	129%	17%	22%
Coal	3	4	4	4	4	5	5	6	1.4%	39%	12%	9%
Nuclear	0	0	0	0	0	0	1	1	8.1%	549%	–%	2%
Biomass/waste	10	13	15	16	17	18	20	20	1.3%	36%	45%	35%
Hydro	0	0	0	1	1	1	1	1	5.2%	239%	1%	2%
Other renewables	0	0	0	0	1	1	1	1	6.6%	365%	1%	2%
Demand by sector												
Total end-use (including electricity)	19	26	29	32	36	40	45	49	2.2%	69%	100%	100%
Residential and commercial	9	12	14	15	17	19	21	23	2.2%	69%	48%	47%
Transportation	3	4	5	6	7	7	8	9	2.8%	94%	17%	19%
Industrial	7	9	10	11	12	13	15	16	1.9%	58%	35%	33%
Memo: electricity demand	1	2	2	3	4	5	6	7	5.2%	236%	8%	15%
Power generation fuel[1]	4	6	7	8	9	12	15	17	4.1%	163%	20%	30%
ASIA PACIFIC												
Primary	123	202	231	250	273	290	305	315	1.3%	36%	100%	100%
Oil	40	52	61	67	74	79	82	85	1.3%	38%	27%	27%
Natural gas	12	21	27	32	37	42	45	48	2.5%	80%	12%	15%
Coal	43	93	103	104	110	113	116	115	0.5%	12%	45%	37%
Nuclear	5	6	5	8	12	15	18	21	6.2%	325%	2%	7%
Biomass/waste	20	23	25	25	25	24	23	22	(0.5)%	(12)%	11%	7%
Hydro	2	4	6	6	7	7	7	7	1.2%	33%	2%	2%
Other renewables	1	2	4	7	9	11	14	17	5.7%	274%	2%	5%
Demand by sector												
Total end-use (including electricity)	96	153	176	190	206	219	229	236	1.2%	35%	100%	100%
Residential and commercial	31	39	45	48	52	55	57	59	1.2%	33%	25%	25%
Transportation	17	26	34	40	45	49	53	56	2.1%	63%	19%	24%
Industrial	47	88	97	102	109	115	119	121	0.9%	25%	55%	51%
Memo: electricity demand	12	24	32	36	42	47	52	57	2.4%	77%	18%	24%
Power generation fuel[1]	41	76	92	100	112	122	132	140	1.8%	53%	40%	44%
EUROPE												
Primary	77	80	75	75	73	72	70	68	(0.4)%	(9)%	100%	100%
Oil	31	29	27	26	26	25	24	23	(0.8)%	(18)%	36%	33%
Natural gas	17	20	18	17	18	18	18	18	0.1%	3%	23%	26%
Coal	14	13	11	10	9	7	6	4	(3.8)%	(61)%	14%	6%
Nuclear	10	10	9	9	8	8	9	9	–%	–%	12%	13%
Biomass/waste	3	5	6	6	6	6	6	6	0.2%	5%	7%	9%
Hydro	2	2	2	2	2	2	2	2	0.3%	8%	3%	3%
Other renewables	0	2	3	4	4	5	6	6	3.2%	112%	4%	9%
Demand by sector												
Total end-use (including electricity)	59	62	59	58	58	57	56	54	(0.3)%	(8)%	100%	100%
Residential and commercial	18	21	19	19	18	18	17	17	(0.5)%	(11)%	32%	31%
Transportation	17	18	18	19	19	19	18	18	(0.1)%	(2)%	31%	33%
Industrial	25	23	22	21	21	20	20	20	(0.4)%	(9)%	37%	36%
Memo: electricity demand	10	12	11	12	12	13	13	14	0.8%	21%	19%	25%
Power generation fuel[1]	30	32	30	31	30	30	30	29	(0.1)%	(3)%	40%	43%

[1]Share based on total primary energy

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change 2016	% change 2016	Share of total	
Regions	**2000**	**2010**	**2016**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2016**	**2040**
LATIN AMERICA												
Primary	19	25	28	30	32	34	37	40	1.5%	42%	100%	100%
Oil	9	11	12	13	14	14	15	16	1.1%	29%	44%	40%
Natural gas	4	6	6	6	7	8	9	11	2.4%	77%	22%	27%
Coal	1	1	1	1	1	1	1	1	0.4%	10%	4%	3%
Nuclear	0	0	0	0	0	1	1	1	3.2%	112%	1%	1%
Biomass/waste	3	4	5	5	5	5	5	5	(0.1)%	(2)%	17%	12%
Hydro	2	2	2	3	3	3	3	4	1.7%	50%	8%	9%
Other renewables	0	1	1	2	2	2	3	3	4.5%	187%	4%	8%
Demand by sector												
Total end-use (including electricity)	17	22	24	26	27	30	32	34	1.5%	43%	100%	100%
Residential and commercial	3	4	4	5	5	5	6	6	1.4%	40%	18%	18%
Transportation	5	7	8	8	9	10	11	11	1.6%	47%	32%	33%
Industrial	9	12	12	13	13	14	15	17	1.4%	41%	50%	49%
Memo: electricity demand	2	3	4	4	5	5	6	7	2.6%	86%	15%	20%
Power generation fuel[1]	4	6	7	8	9	10	11	12	2.0%	62%	27%	31%
MIDDLE EAST												
Primary	17	28	34	37	40	44	46	48	1.4%	40%	100%	100%
Oil	10	14	16	17	18	19	19	20	0.8%	21%	48%	41%
Natural gas	7	13	17	19	22	23	25	26	1.7%	49%	51%	54%
Coal	0	0	0	0	0	0	0	0	(3.9)%	(62)%	1%	–%
Nuclear	0	0	0	0	0	1	1	1	14.4%	2426%	–%	2%
Biomass/waste	0	0	0	0	0	0	0	0	7.6%	485%	–%	–%
Hydro	0	0	0	0	0	0	0	0	2.3%	73%	–%	–%
Other renewables	0	0	0	0	0	0	1	1	9.2%	720%	–%	1%
Demand by sector												
Total end-use (including electricity)	13	22	27	29	31	34	36	38	1.5%	43%	100%	100%
Residential and commercial	3	4	5	5	6	6	7	7	1.8%	53%	17%	19%
Transportation	4	6	8	8	9	9	10	10	1.2%	34%	29%	27%
Industrial	7	11	14	15	17	19	20	21	1.5%	44%	54%	54%
Memo: electricity demand	1	3	3	4	4	5	6	6	2.9%	100%	12%	17%
Power generation fuel[1]	5	9	11	12	14	15	16	16	1.7%	51%	32%	34%
NORTH AMERICA												
Primary	110	109	109	110	112	114	113	111	0.1%	3%	100%	100%
Oil	44	43	43	43	44	44	43	42	(0.1)%	(2)%	39%	38%
Natural gas	26	28	33	34	36	39	39	40	0.9%	23%	30%	36%
Coal	23	21	14	13	11	10	8	6	(3.3)%	(55)%	13%	6%
Nuclear	9	10	10	9	9	9	9	9	(0.3)%	(7)%	9%	8%
Biomass/waste	4	3	3	3	3	3	3	3	(0.2)%	(5)%	3%	3%
Hydro	2	2	2	2	2	3	3	3	0.9%	24%	2%	3%
Other renewables	1	2	3	4	5	6	7	7	3.6%	131%	3%	7%
Demand by sector												
Total end-use (including electricity)	82	82	84	86	89	91	91	90	0.3%	8%	100%	100%
Residential and commercial	22	23	21	22	22	22	22	22	0.1%	3%	26%	25%
Transportation	28	30	31	32	32	32	32	31	–%	–%	38%	35%
Industrial	32	30	31	32	35	36	37	37	0.7%	18%	37%	41%
Memo: electricity demand	14	16	16	16	17	18	19	19	0.8%	20%	19%	21%
Power generation fuel[1]	42	43	41	40	40	41	41	40	–%	(1)%	38%	36%

[1]Share based on total primary energy

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
Regions	2000	2010	2016	2020	2025	2030	2035	2040	2016 2040	2016 2040	2016	2040
RUSSIA/CASPIAN												
Primary	37	42	41	41	41	41	40	40	(0.2)%	(4)%	100%	100%
Oil	7	8	9	10	10	10	10	10	0.3%	7%	23%	25%
Natural gas	20	23	21	21	21	20	20	19	(0.4)%	(10)%	51%	48%
Coal	7	7	7	6	6	5	5	5	(1.4)%	(29)%	16%	12%
Nuclear	2	3	3	3	4	4	4	4	1.9%	57%	7%	11%
Biomass/waste	0	0	0	0	0	0	0	0	—%	—%	1%	1%
Hydro	1	1	1	1	1	1	1	1	—%	1%	2%	2%
Other renewables	0	0	0	0	0	0	0	0	9.6%	800%	—%	—%
Demand by sector												
Total end-use (including electricity)	29	33	33	33	33	33	33	32	(0.1)%	(2)%	100%	100%
Residential and commercial	9	9	9	9	9	9	8	8	(0.5)%	(12)%	28%	25%
Transportation	3	4	5	5	5	5	5	5	0.1%	4%	14%	15%
Industrial	17	20	19	19	19	20	19	19	0.1%	1%	58%	60%
Memo: electricity demand	3	4	4	4	5	5	5	6	1.1%	30%	13%	17%
Power generation fuel[1]	19	20	19	19	18	18	18	18	(0.2)%	(6)%	46%	45%
GDP by region (2010$, trillions)												
World	50	66	77	86	100	115	132	150	2.8%	95%	100%	100%
OECD	38	44	49	53	58	64	70	77	1.9%	56%	64%	51%
Non-OECD	12	21	28	33	42	51	62	73	4.1%	163%	36%	49%
Africa	1	2	2	3	3	4	5	6	3.9%	151%	3%	4%
Asia Pacific	12	19	25	29	36	44	52	61	3.8%	147%	32%	41%
China	2	6	9	12	16	20	24	29	4.8%	205%	12%	19%
India	1	2	3	3	5	6	8	10	5.9%	299%	3%	7%
Europe	16	19	20	22	24	26	28	30	1.7%	49%	27%	20%
European Union	15	17	18	19	21	23	25	26	1.6%	45%	24%	18%
Latin America	3	4	5	5	6	7	8	9	2.8%	95%	6%	6%
Middle East	1	2	3	3	3	4	5	6	3.2%	115%	3%	4%
North America	15	18	20	22	24	27	31	34	2.3%	71%	26%	23%
United States	13	15	17	18	21	23	26	29	2.2%	70%	22%	19%
Russia/Caspian	1	2	2	2	3	3	3	4	2.1%	65%	3%	3%
Energy intensity (thousand BTU per $ GDP)												
World	8.1	7.8	7.2	6.7	6.1	5.6	5.0	4.5	(1.9)%	(37)%		
OECD	5.7	5.0	4.4	4.1	3.8	3.4	3.1	2.8	(2.0)%	(38)%		
Non-OECD	15.9	13.7	12.1	10.8	9.5	8.3	7.3	6.4	(2.6)%	(47)%		
Africa	18.6	14.9	13.8	13.1	12.1	11.3	10.5	9.7	(1.4)%	(30)%		
Asia Pacific	10.4	10.7	9.4	8.5	7.6	6.6	5.9	5.1	(2.5)%	(45)%		
China	20.4	16.8	12.5	10.4	8.6	7.1	6.0	5.1	(3.7)%	(59)%		
India	21.3	16.0	14.1	12.3	10.5	8.9	7.7	6.5	(3.1)%	(54)%		
Europe	4.7	4.2	3.7	3.4	3.1	2.8	2.5	2.3	(2.0)%	(39)%		
European Union	4.8	4.3	3.7	3.4	3.0	2.7	2.4	2.2	(2.1)%	(41)%		
Latin America	6.4	6.0	6.2	6.0	5.6	5.2	4.8	4.5	(1.3)%	(27)%		
Middle East	12.5	13.1	13.4	12.7	11.7	10.8	9.7	8.7	(1.8)%	(35)%		
North America	7.3	6.2	5.5	5.0	4.6	4.1	3.7	3.3	(2.1)%	(40)%		
United States	7.3	6.0	5.3	4.9	4.4	4.0	3.5	3.1	(2.2)%	(41)%		
Russia/Caspian	29.5	19.7	18.0	16.5	14.8	13.1	11.7	10.5	(2.2)%	(42)%		
Energy-related CO_2 emissions (billion tonnes)												
World	23.7	31.1	32.7	33.5	35.0	35.9	36.4	36.3	0.4%	11%	100%	100%
OECD	12.9	12.9	12.2	11.9	11.5	11.2	10.7	10.1	(0.8)%	(17)%	37%	28%
Non-OECD	10.8	18.2	20.5	21.6	23.5	24.7	25.7	26.3	1.0%	28%	63%	72%
Africa	0.9	1.2	1.3	1.4	1.7	1.9	2.2	2.4	2.7%	90%	4%	7%
Asia Pacific	7.4	13.6	15.4	16.2	17.4	18.1	18.7	18.9	0.8%	22%	47%	52%
China	3.2	7.9	8.7	8.8	9.3	9.3	9.2	8.9	0.1%	2%	27%	25%
India	0.9	1.6	2.3	2.7	3.2	3.6	4.0	4.3	2.6%	87%	7%	12%
Europe	4.4	4.3	3.9	3.8	3.6	3.4	3.1	2.9	(1.2)%	(25)%	12%	8%
European Union	4.0	3.9	3.4	3.3	3.1	2.9	2.6	2.4	(1.5)%	(30)%	11%	7%
Latin America	0.9	1.2	1.3	1.4	1.5	1.7	1.8	1.9	1.4%	39%	4%	5%
Middle East	1.1	1.8	2.1	2.3	2.4	2.5	2.6	2.6	0.9%	23%	7%	7%
North America	6.7	6.6	6.2	6.1	6.1	6.0	5.8	5.5	(0.5)%	(11)%	19%	15%
United States	5.8	5.6	5.1	5.1	5.0	4.9	4.7	4.4	(0.6)%	(14)%	16%	12%
Russia/Caspian	2.3	2.5	2.4	2.3	2.3	2.2	2.2	2.1	(0.6)%	(14)%	7%	6%

[1]Share based on total primary energy

Glossary

Billion cubic feet per day (BCFD): A standard unit used to define volumetric rates of natural gas. One billion cubic feet per day of natural gas is enough to meet about 2 percent of the natural gas used in homes around the world. Six billion cubic feet per day of natural gas is equivalent to about 1 million oil-equivalent barrels per day.

British thermal unit (BTU): A BTU is a standard unit of energy that can be used to measure any type of energy source. The energy content of one gallon of gasoline is about 120,000 BTUs. "Quad" refers to a quadrillion (10^{15}) BTUs. In the 2018 *Outlook for Energy*, energy content in BTUs for each oil product (e.g., gasoline, diesel, LPG, etc.) is based on its specific energy density.

Conventional vehicle: A type of light-duty vehicle with an internal combustion engine, typically either a gasoline-fueled spark ignition engine or a diesel-fueled compression ignition engine. Conventional includes vehicles with advanced technologies such as turbocharging and "mild hybrid" features such as a stop-start engine.

Exajoule: A joule is a standard unit that can be used to measure any type of energy. 1 exajoule = 10^{18} joules, roughly equivalent to 1 quadrillion BTUs.

Generation efficiency: The ratio of useful energy output to energy input in the generation of electricity from primary energy sources. Generation efficiency typically varies by generation type and region, however wind, solar PV and hydro are assumed to be 100 percent efficient.

Hybrid vehicle: A "full" hybrid is a type of light-duty vehicle that has a battery (usually a nickel metal hydride) and an electric motor, as well as a conventional internal combustion engine. When brakes are applied, the energy of the moving vehicle is stored in the battery and can be used later, thus saving fuel.

Hydrogen fuel cell vehicle: A type of light-duty vehicle for which hydrogen is the fuel and is stored onboard. This hydrogen is passed through a fuel cell that then provides electricity to power the vehicle.

Light-duty vehicle (LDV): A classification of road vehicles that includes cars, light trucks and sport utility vehicles (SUVs). Motorcycles are not included in the light-duty vehicle fleet size or fuel-economy, but the fuel used in motorcycles is included in light-duty transportation demand.

Liquefied natural gas (LNG): Natural gas (predominantly methane) that has been super-chilled for conversion to liquid form for ease of transport.

Liquefied petroleum gas (LPG): A classification of hydrocarbon fuel including propane, butane and other similar hydrocarbons with low molecular weight.

Million oil-equivalent barrels per day (MBDOE): A standardized unit of measure for different types of energy sources (natural gas, coal, etc.) based on energy content relative to a typical barrel of oil. One million oil-equivalent barrels per day is enough energy to fuel about 4 percent of the light-duty vehicles on the world's roads today. Reporting for all energy types in MBDOE is done on an oil-equivalent basis, with the exception of oil products, which are reported in physical barrels.

Natural gas liquid (NGL): A liquid fuel produced chiefly in association with natural gas. NGLs are components of natural gas that are separated from the gaseous state into liquid form during natural gas processing. Ethane, propane, butane, isobutane and pentane are all NGLs.

Organisation for Economic Co-operation and Development (OECD): A forum for about 35 nations from across the world that work with each other, as well as with many more partner nations, to promote policies that will improve the economic and social well-being of people around the world.

Plug-in hybrid electric vehicle (PHEV): A type of light-duty vehicle that typically uses an electric motor. Unlike other electric vehicles, a PHEV also has a conventional internal combustion engine that can charge its battery using petroleum fuels if needed, and in some cases power the vehicle.

PPP: Purchasing power parity.

Primary energy: Includes energy in the form of oil, natural gas, coal, nuclear, hydro, geothermal, wind, solar and bioenergy sources (biofuels, municipal solid waste, traditional biomass). It does not include electricity or market heat, which are secondary energy types reflecting conversion/production from primary energy sources.

Secondary energy: Energy types, including electricity and market heat, that are derived from primary energy sources. For example, electricity is a secondary energy type generated using natural gas, wind or other primary energy sources.

TCF: Trillion cubic feet

Watt: A unit of electrical power, equal to one joule per second. A 1-gigawatt power plant can meet the electricity demand of more than 500,000 homes in the United States. Kilowatt (kW) = 1,000 watts; gigawatt (GW) = 1,000,000,000 watts; terawatt (TW) = 10^{12} watts.

Watt-hour: A unit of electrical energy. 300 terawatt hours is equivalent to about 1 quadrillion BTUs (quad). Kilowatt-hour (kWh) = 1,000 watt-hours; gigawatt-hour (GWh) = 1,000,000,000 watt-hours; terawatt-hour (TWh) = 10^{12} watt-hours.

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