2019 OUTLOOK FOR ENERGY: A PERSPECTIVE TO 2040

ExxonMobil


DUAL CHALLENGE

OUTLOOK FOR ENERGY: A PERSPECTIVE TO 2040

The 2019 *Outlook for Energy* is ExxonMobil's latest view of energy demand and supply through 2040. For many years the *Outlook* has helped inform ExxonMobil's long-term business strategies, investment plans and research programs.

The Dual Challenge

As energy is essential for human development, society faces a dual challenge: to provide reliable and affordable energy to a growing population, while reducing environmental impacts, including the risks of climate change.

A significant portion of the world's population remains energy-deprived, facing living conditions that would be considered dire by most people in developed countries. Access to modern energy improves a community's quality of life; it is closely correlated to increased life expectancy, reduced poverty and malnutrition, and higher levels of childhood education.

As growing populations gain increased access to energy, rising living standards in many parts of the world will create the largest expansion of the global middle class in history, meaning more demand for homes, transportation, electricity, consumer goods and the energy to power them all. The challenge is to satisfy this growing demand, while reducing the risks of climate change.

Building a perspective

The *Outlook* provides a projection of energy demand through 2040 using the International Energy Agency (IEA) and other credible third-party sources as a foundation. The projection is based on likely trends in technology, policy, consumer preferences, geopolitics and economic development. While these individual trends may vary over time, the snapshot provided by the *Outlook* can help to evaluate society's progress toward addressing both aspects of the dual challenge.

As these trends evolve, we continue to discuss our approach and conclusions with numerous stakeholder groups, economists and policy experts. The *Outlook* team also considers various sensitivities and third-party scenarios from peer-reviewed work to improve our understanding of the energy landscape.

Addressing the dual challenge will have ramifications for every nation's economic, energy security and environmental goals. By sharing our *Outlook* with the public, we seek to broaden understanding of the world's energy system and enrich the dialogue on practical, robust solutions.

ExxonMobil supports the Paris Agreement

The Paris Agreement[1] on climate change declared governments' intentions to reduce greenhouse gas (GHG) emissions as outlined in each country's nationally determined contribution (NDCs). Many states, cities and businesses, including ExxonMobil, expressed support for the aims of the agreement. Our own climate change risk management strategy is described in ExxonMobil's *Energy & Carbon Summary,* which can be found at exxonmobil.com.

Based on the *Outlook* and third-party reports, including the 2018 Emissions Gap Report from the United Nations Environment Programme, we expect that the world is likely to meet, in aggregate, the 2030 Paris Agreement pledges with continued focused efforts, but further work is needed for the world to accelerate progress toward a 2°C pathway.[2]

Our 2019 *Outlook*, like the 2018 *Outlook*, includes a section, "Pursuing a 2°C Pathway", utilizing third-party, peer-reviewed work coordinated by the Energy Modeling Forum at Stanford University[3]. The discussion in this section highlights the need for enabling technologies and policies, a role for all primary energy sources, and the continued need for focused investments, including in oil and natural gas.

We believe technology holds the greatest potential to help society address the dual challenge. Technology has already significantly improved energy efficiency and helped to unlock diverse and abundant sources of energy. To address the dual challenge, no technology or energy type can be ignored. Instead, the world must harness a variety of energy sources and technology advances, guided by policies that fully reflect the costs and benefits, consumer preferences and the need to provide affordable energy to all.

Progress toward tackling the dual challenge requires thoughtful and meaningful action by everyone - policymakers, business leaders, technologists and consumers. ExxonMobil is committed to doing our part. As one of the world's premier energy and technology companies, we are well-positioned to continue providing safe, reliable energy today and effective solutions to meet the word's future energy needs - all while reducing environmental impacts and mitigating the risks of climate change.

Energy matters to everyone and we all play a role in shaping its future.

KEY TAKEAWAYS OF 2040 PROJECTIONS

Energy is fundamental for modern life

Access to modern energy is intrinsically linked with improvements in quality of life. Over the next few decades, increasing populations and rising prosperity will increase demand for homes, businesses and transportation - and the energy that powers them.

Global energy demand rises by 20 percent; market demand trends differ for OECD and non-OECD

Continued innovation will help OECD economies expand while reducing their energy demand by about 5 percent and energy-related CO_2 emissions by nearly 25 percent. In the non-OECD countries however, energy use and emissions will rise along with population growth, increased access to modern energy and improving living standards.

Global electricity demand rises 60 percent

The trend to further electrify buildings, factories, cars and buses, along with smart appliances and greater automation, spurs the need for more electricity everywhere. Solar, wind and natural gas contribute the most to meeting growth in electricity demand.

Almost half of the world's energy is dedicated to industrial activity

New homes and roads will be constructed and household appliances produced as a result of rising population and urbanization. Steel, cement and chemicals are essential materials to satisfy these needs which, today, are energy-intensive products.

Commerce and trade drive transportation energy consumption up more than 25 percent

Increased on-road efficiency and more electric vehicles will lead to a decline in light-duty vehicle liquid fuel demand. Overall transportation fuel demand growth is driven by increased commercial activity - moving more people and products by bus, rail, plane, truck and marine vessel. Energy-dense, affordable and widely available oil will remain the predominant transportation fuel.

Global energy-related CO_2 emissions peak, but remain above assessed 2°C scenarios

Increased energy efficiency and a shift to lower carbon energy sources will help curb CO_2 emissions, but not sufficiently to reach a 2°C pathway.[2] Innovative technology solutions and supportive policies are still needed to achieve society's emissions aspirations.

Oil and natural gas remain important energy sources and require significant investment

Oil and natural gas make up about 55 percent of global energy use today. By 2040, 10 of the 13 assessed 2°C scenarios project that oil and gas will continue to supply more than 50 percent of global energy. Investment in oil and natural gas is required to replace natural decline from existing production and to meet future demand under all assessed 2°C scenarios.

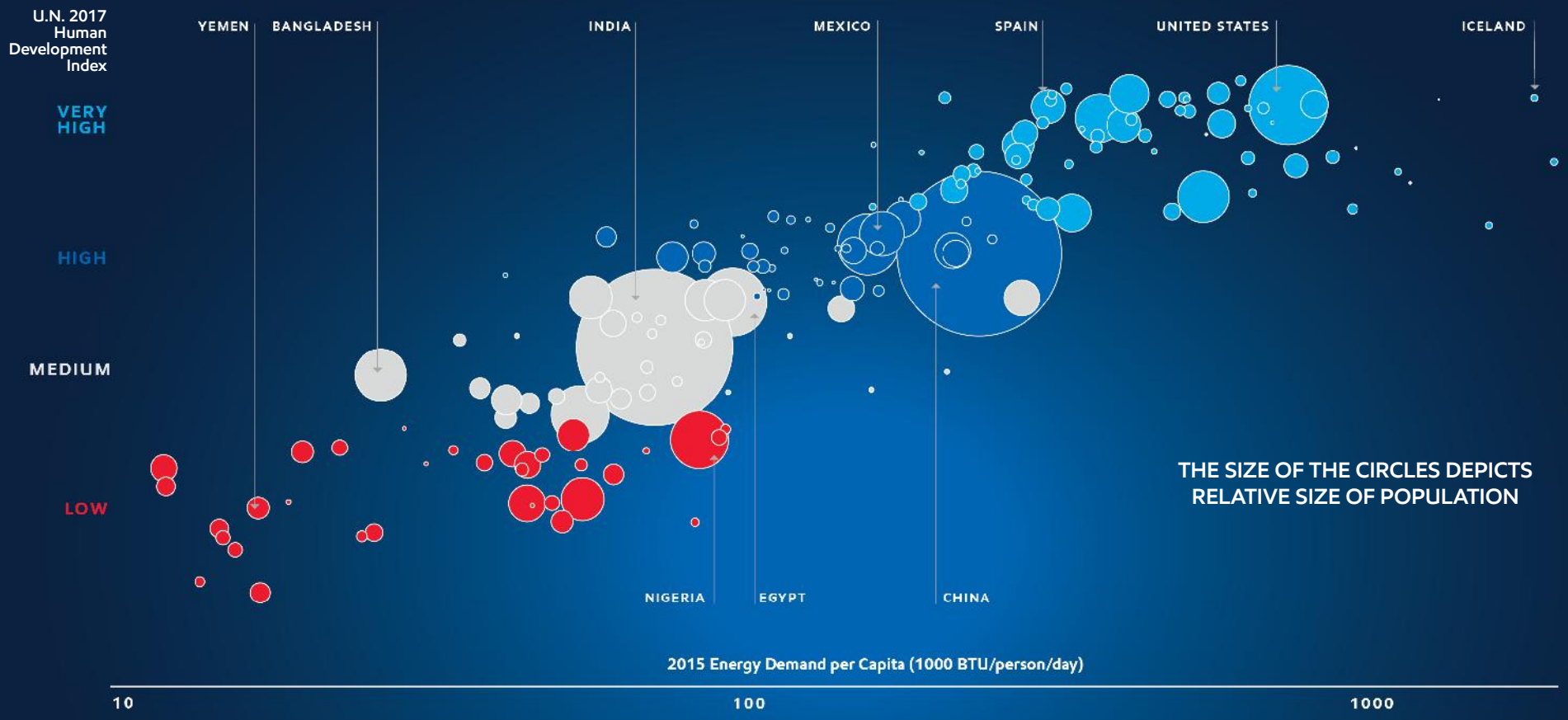
CONTENTS

FUNDAMENTALS

Energy is essential for society's progress. Economic expansion and improving access to energy enable longer, more productive lives for the growing global population.

Society's progress is intrinsically related to energy. Access to safe, reliable and affordable energy is a critical enabler of higher living standards, including a longer and healthier life. Today a significant portion of the global population still faces serious challenges in accessing energy on a daily basis, negatively impacting health and preventing many from fully realizing their potential. The challenges become even greater considering that by 2040 the global population is projected to grow to 9.2 billion from 7.5 billion today.

Improving access to energy and a growing global economy will lead to better economic opportunities, higher incomes and improved living conditions for many. As countries move up the human development index, the improving living standards are associated with increased energy use. Today, almost 50 percent of the global population lives in countries that rank low to medium on the U.N.'s human development index. Advancing development for nearly half the world's population creates the potential for significant global energy growth.

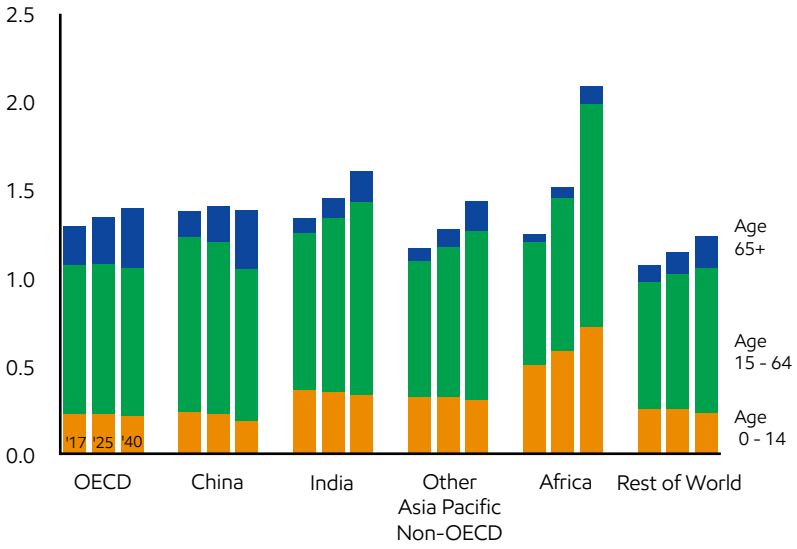


Source U.N. Human Development Reports 2018, World Bank DataBank 2019, EM analyses, updated 9/11/2019

GLOBAL FUNDAMENTALS – PROJECTIONS

World demographics continue to shift

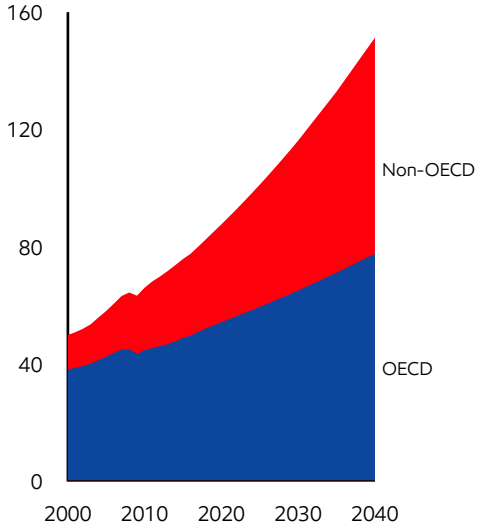
Billions of people



- By 2040, the global population will reach 9.2 billion people, up from 7.5 billion today; India will soon surpass China as the most populous nation, but the most profound growth is in Africa
- Significant increases in prime working-age population in Africa, India and other Asia Pacific (AP) non-OECD countries contribute to the energy needs of these regions
- The rising youth population in Africa and maturing populations in the OECD and China will also influence the future of the global economy and energy demand
- These demographic trends impact global energy markets with geographic shifts in where and how energy is produced, transported and used

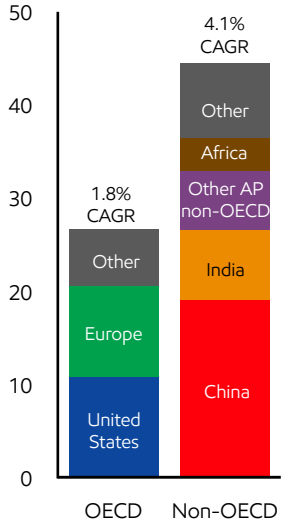
World GDP doubles

Trillions of 2010 dollars



Non-OECD leads growth

Trillions of 2010 dollars GDP 2017-2040

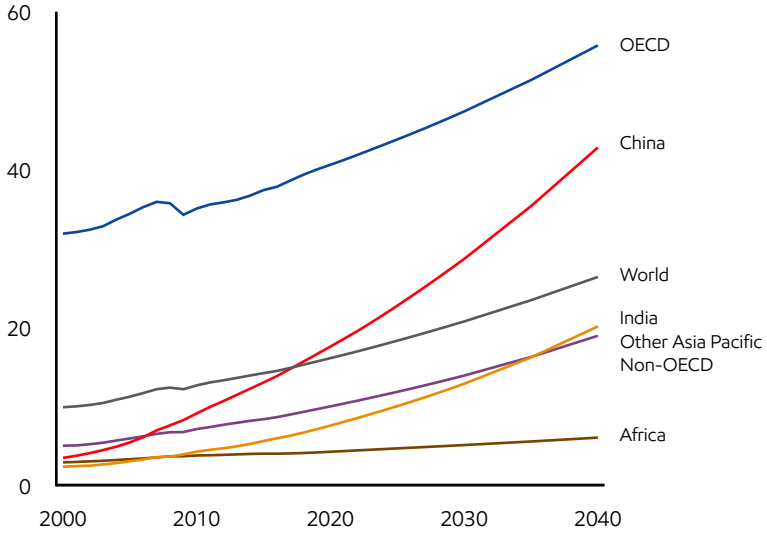


- Economic expansion is a key driver of energy demand. World GDP is projected to nearly double from 2017 to 2040 with the non-OECD growing at more than twice the rate of the OECD
- By 2040, the non-OECD countries will account for about half of global GDP, up from about a third today. China and India's combined growth is nearly the same as the OECD
- The widespread non-OECD economic expansion suggests continued robust demand for energy in these economies
- GDP for the OECD countries grows at a slower pace but from a much higher base than the non-OECD countries.

GLOBAL FUNDAMENTALS – PROJECTIONS

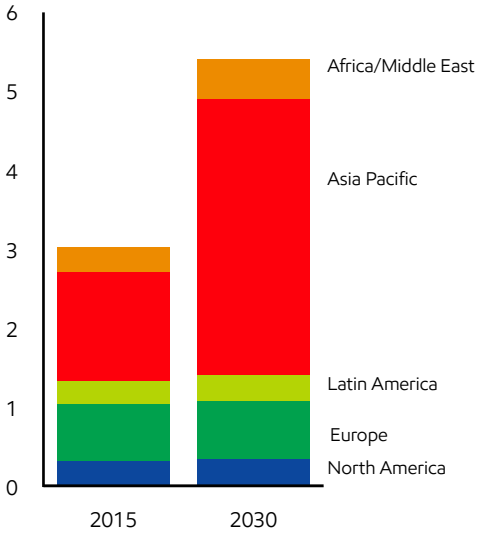
Purchasing power expands

GDP per capita – thousands of purchasing power parity dollars



Middle class almost doubles

Global middle class – billions of people



Source: The Brookings Institution - Global Economy & Development 2017

- Access to modern energy enables economic progress and improves quality of life. As income grows, it enables a family to own a home, purchase labor-saving appliances, pursue an education, travel and obtain needed medical treatment
- As GDP grows faster than population around the globe, average personal incomes rise everywhere, albeit with significant country and regional variations
- By 2040, China GDP per capita is expected to triple and be at about 75 percent of the OECD
- Over the *Outlook* period, India per capita GDP level is likely to grow even faster than China, but remaining below the global average. Africa only achieves an average 50 percent increase

- Even though the average income in the non-OECD countries remains lower than in the OECD, there is already a burgeoning middle class that can afford more than the basic necessities of food and shelter. The Brookings Institution foresees continued rapid growth of the global middle class, with billions more people rising out of poverty by 2030
- Asia Pacific represents the largest growth, with India and China each expected to have more than 1 billion middle-class citizens by 2030
- The expanding middle class means billions of people will aim to improve their living conditions and access to energy is a critical enabler for these aspirations

GLOBAL FUNDAMENTALS – PROJECTIONS

Technology enables energy efficiency

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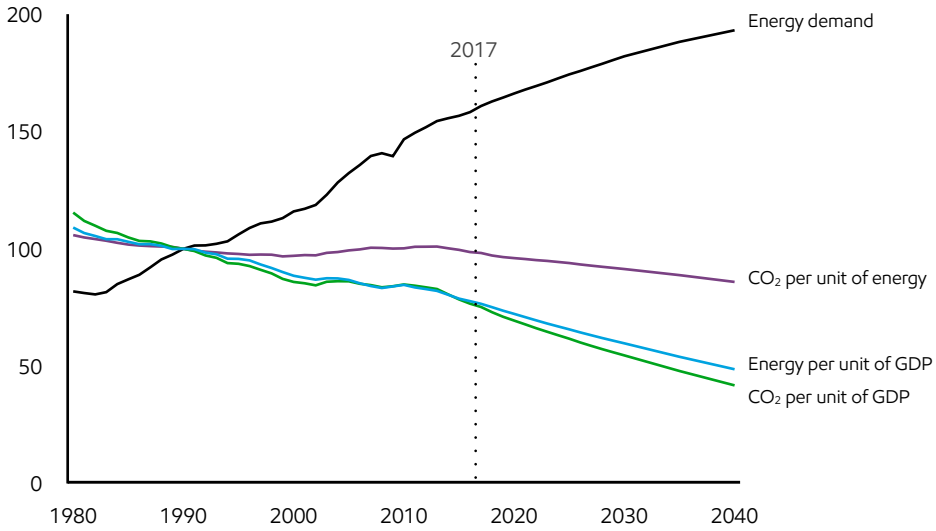
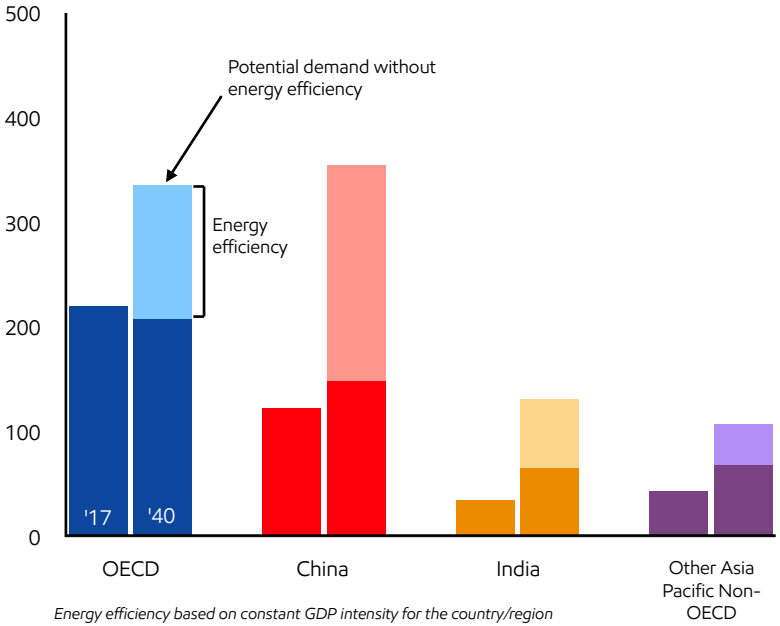


- Technology advances and choices by consumers and businesses to use energy more efficiently can moderate growth in energy demand even as the economy expands
- Energy intensity measures the amount of energy used to produce a unit of GDP. Global energy intensity is expected to improve at nearly 2 percent per year from 2017 to 2040, more than double the pace of improvement from 2000 to 2017
- Meanwhile, the carbon intensity of energy (energy-related CO_2 emissions per unit of energy consumed) is also expected to trend down as policies drive efficiency and aim for a lower-carbon energy mix in pursuit of national climate policy goals
- By 2040 the combined effects of lower energy intensity and less carbon-intensive energy sources result in a nearly 45 percent reduction in the carbon intensity of the global economy (tonnes energy-related CO_2 emissions per unit of GDP)

Global efficiency limits demand growth

Energy demand – quadrillion British thermal units (BTUs)



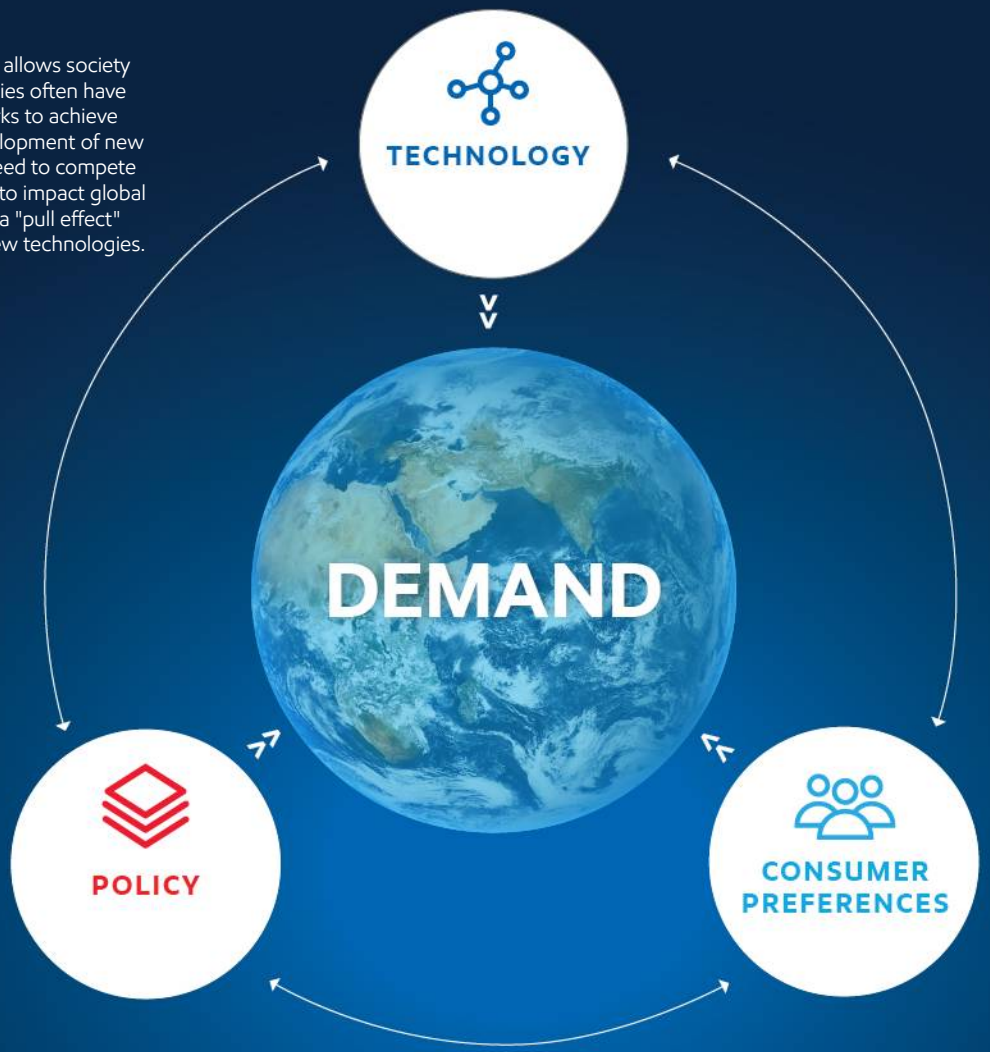
Energy efficiency based on constant GDP intensity for the country/region

- Hypothetically, if energy intensity remained the same over time, global energy demand would grow in lock step with GDP, almost doubling between 2017 and 2040
- However, global energy demand is projected to grow only by about 20 percent from 2017 to 2040 because continued efficiency improvement lowers the energy intensity of the global economy
- OECD demand is expected to decline about 5 percent from 2017 to 2040 despite about 50 percent GDP growth as efficiency more than offsets the underlying growth drivers
- All of the projected energy demand growth is expected to be from the non-OECD countries, led by China and India. There, the implied energy savings are not enough to offset the inherent demand growth driven by population and economic growth

DEMAND: THREE DRIVERS

Policy. Technology. Consumer preferences. All three impact how the world uses energy. Each driver influences the other. The interplay between these can vary depending on local circumstances (available resources, public support) and can change over time. At ExxonMobil, we're continually studying energy demand and developing models that measure its potential impact — all in an effort to gain a deeper understanding of the interconnectivity of the global energy system.

TECHNOLOGY: Deploying new technology allows society to do more with less. Most successful technologies often have the supporting policy and commercial frameworks to achieve scale. A policy, like tax incentives, can spur development of new technology, but these technologies ultimately need to compete without subsidies to reach a large enough scale to impact global markets. Consumer preferences can also create a "pull effect" that increases demand in the marketplace for new technologies.



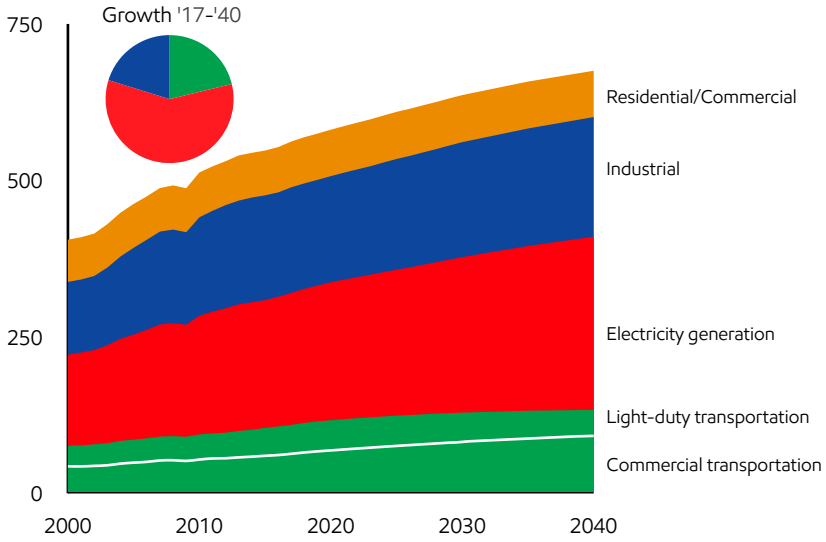
POLICY: Shifts in policy can stimulate new technology and influence consumer choices. For example, policies can encourage adoption of new technology (free parking for electric vehicles) or discourage the use of an existing technology (restrictions on coal-based power). The corollary is also true: policy not enabled by competitive technology or not aligned with consumer preferences can be difficult to implement because it is hard to mandate something that isn't better than current options in the eyes of the consumer.

CONSUMER PREFERENCES: Demand for energy begins with the numerous choices consumers make in their daily lives. These preferences can shift as new technology enables options that better meet a consumer's needs, such as lower energy costs and lower emissions. Consumer preferences can also be altered over time by policies that incentivize choices, like a carbon tax that encourages more lower carbon electricity supply.

DEMAND — PROJECTIONS

Global energy demand varies by sector

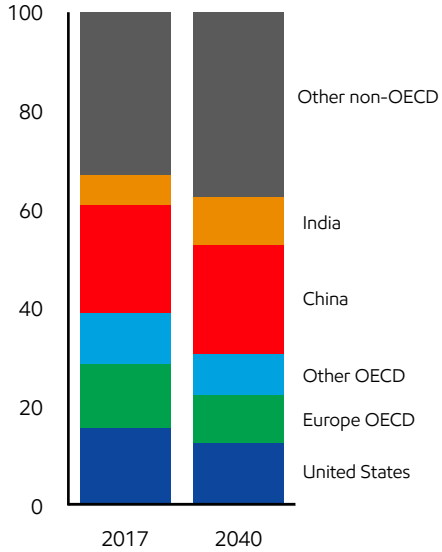
Primary energy – quadrillion BTUs



- Global demand reaches 675 quadrillion BTUs in 2040, up ~20 percent versus 2017, reflecting a growing population and rising prosperity
- Residential and commercial energy demand is flat out to 2040 as efficiency improvements offset the energy needs of a growing population
- Electricity generation is the largest and fastest-growing sector, primarily reflecting expanding access to reliable electricity in developing countries
- Industrial sector growth supports construction of buildings and infrastructure, and manufacturing of a variety of products to meet the needs of the world's population
- Commercial transportation grows with expanding economies, which increase the movement of goods. Personal mobility also expands, but efficiency improvements and more electric vehicles offset the increase in vehicle miles traveled

Energy demand led by non-OECD

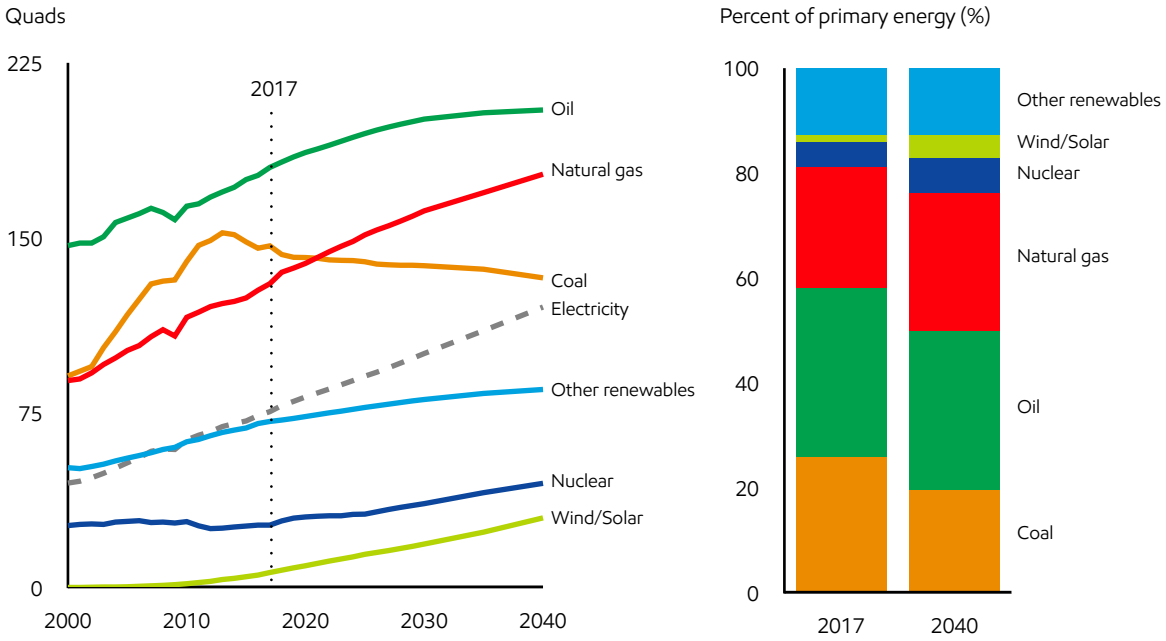
Percent of primary energy (percent)



- Global energy consumption continues to shift proportionally to developing economies where population and economic growth are both faster than the global average. Non-OECD share of global energy demand reaches ~70 percent in 2040
- China and India contribute ~50 percent of the world's energy demand growth to 2040
- Efficiency gains outpace economic growth in the OECD, which helps offset energy demand increases historically linked to economic expansion
- The combined share of energy used in the United States and European OECD nations declines from about 30 percent in 2017 to less than 25 percent in 2040

DEMAND – PROJECTIONS

Global energy mix shifts to lower-carbon fuels



- Oil continues to play a leading role in the world's energy mix, with growing demand driven by commercial transportation and feedstocks for the chemicals industry
- Natural gas grows the most of any energy type, reaching a quarter of all demand
- Renewables and nuclear see strong growth, contributing more than 40 percent of incremental energy supplies to meet demand growth
- Coal use remains significant in parts of the developing world, but drops below 20 percent global share as China and OECD nations transition toward lower-carbon sources like renewables, nuclear and natural gas
- Electricity, an energy carrier and not an energy source, grows ~3X faster than overall energy demand

Visit energyfactor.com to learn more about technology and innovations such as our cogeneration operations generating electricity and heat that are helping make operations more energy efficient.

TRANSPORTATION — PROJECTIONS

Commerce and trade drive transportation energy consumption up more than 25 percent

Over the past few decades the movement of people and goods has grown dramatically, driven by vast growth in the purchasing power of individuals. Likewise, technology advancements have provided new and more efficient mobility options.

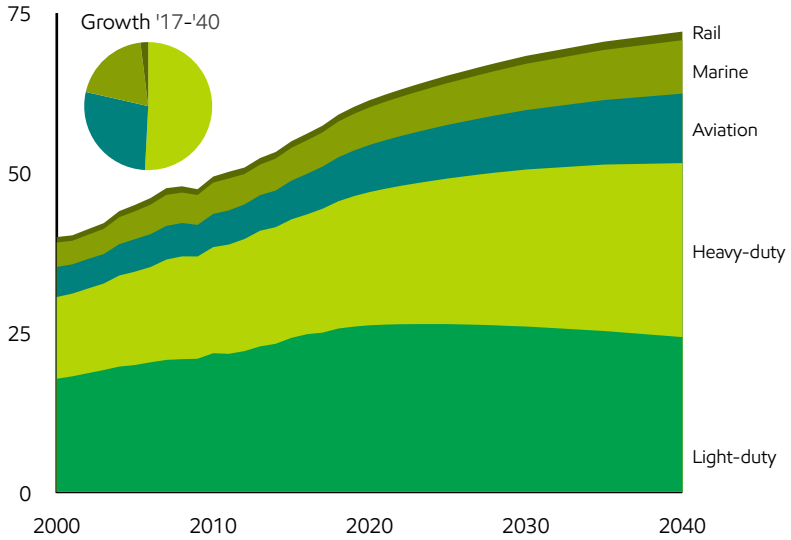
Global transportation demand is driven by differing trends for commercial transportation and light-duty passenger vehicles. As economic activity expands, especially in developing regions, commercial transportation is expected to grow. The majority of the growth comes from heavy-duty trucking as a result of goods movement, but increased aviation travel also plays a role as individual purchasing power expands.

Passenger vehicle ownership is expected to expand as a result of the dramatic growth in the middle class and increased urbanization, leading to increased passenger vehicle travel. The fuel mix continues to evolve with more alternatives, like electric vehicles (BEV and PHEV).

In the *2018 Outlook,* hypothetical sensitivities for light-duty demand showed that for every additional 100 million EVs on the road, liquids demand could fall by ~1.2 million barrels per day in 2040. In a 100 percent light-duty EV sensitivity by 2040, light-duty liquids demand could see 100 percent displacement while growth in chemicals and commercial transportation offset much of the decline resulting in similar liquids demand as seen in 2013. This 100 percent EV sensitivity by 2040 would require all passenger vehicle sales to be electric starting in 2025.

Transportation energy demand growth driven by commerce

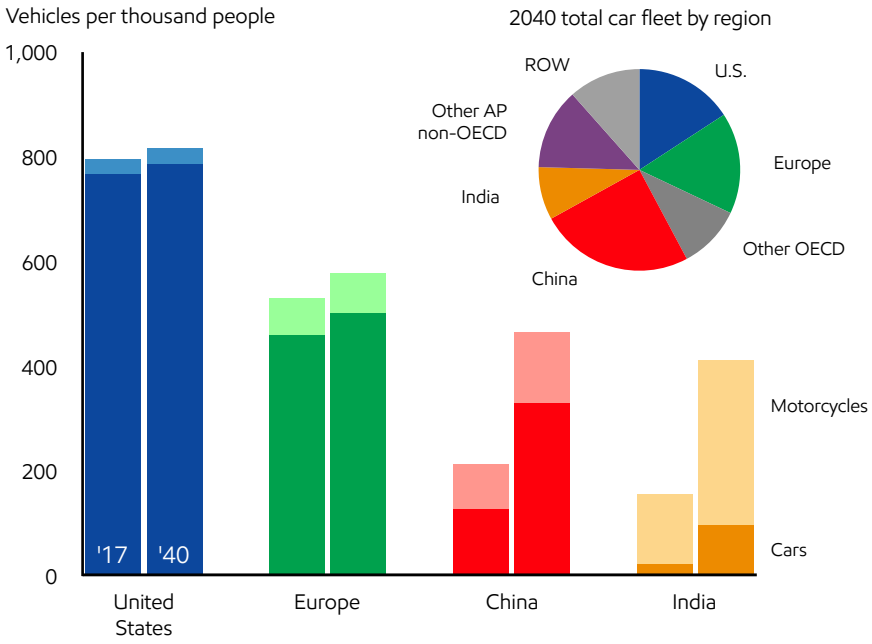
Global sector demand – million oil-equivalent barrels per day (MBDOE)



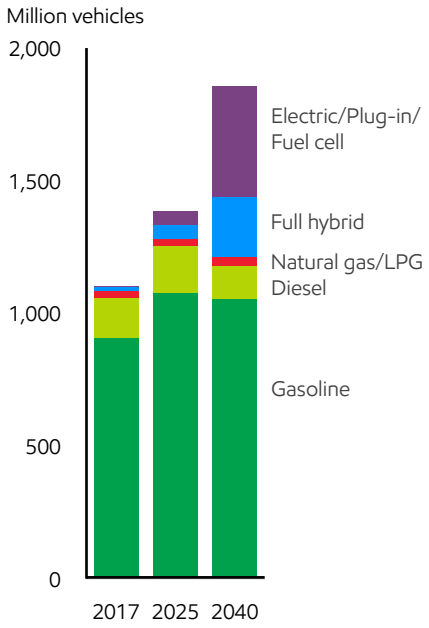
- Global transportation-related energy demand is expected to grow by more than 25 percent from 2017 to 2040
- Personal vehicle ownership continues to grow as purchasing power rises, however, higher efficiency and more electric vehicles lead to a peak and decline in light-duty vehicle energy demand in the mid-2020s
- Commercial transportation (heavy-duty, aviation, marine and rail) energy demand is driven by growth in economic activity and personal buying power, which drives increasing trade of goods and services
- Aviation demand sees the highest annual growth rate at 2.2 percent from 2017 to 2040 due to both rising economic activity as well as rapid growth of the middle class, specifically in emerging economies

TRANSPORTATION — LIGHT-DUTY PROJECTIONS

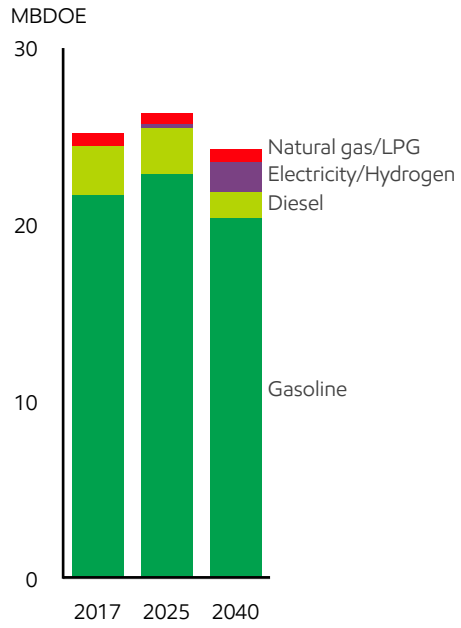
Access to personal mobility increases



Light-duty fleet by type



Light-duty demand by fuel



- When individual purchasing power increases, access to personal mobility also increases, driving growth of the global fleet of light-duty vehicles and motorcycles
- Motorcycles offer a lower-cost entry point to personal mobility, with ownership and growth particularly high in Asia Pacific
- Increasing access to vehicles drives a worldwide increase in personal mobility-related energy demand growth, with Asia Pacific leading the growth
- In the OECD (such as U.S. and Europe), while the number of cars per 1,000 people increases by about 10 percent, passenger vehicle fuel demand declines about 30 percent on average as a result of efficiency gains and powertrain diversification

- In 2017, the global fleet was about 1.1 billion vehicles, with ~3 million (0.3 percent) of the fleet being plug-in hybrids, battery electric & fuel cells
- By 2040, these advanced vehicles grow to over 20 percent of the fleet (~420 million) and nearly 30 percent of new car sales, driven by decreasing battery costs and policies for tailpipe emissions, efficiency and energy independence for importing countries
- Light-duty vehicle demand for internal combustion engine (ICE) fuels are projected to peak prior to 2025 and then decline to levels seen in the early-2010s by 2040
- The reduction in fuel demand, while driven in part by electrification, is mostly connected with efficiency gains across all vehicle types

TRANSPORTATION — COMMERCIAL TRANSPORTATION PROJECTIONS

Global transportation energy demand relative to GDP

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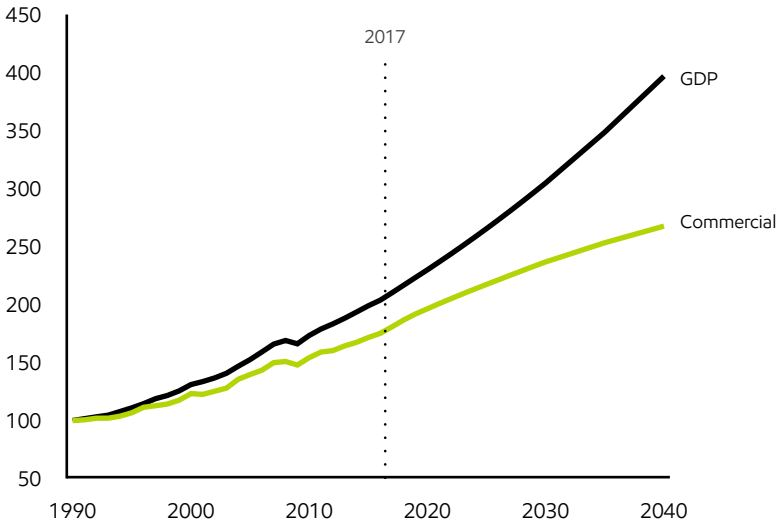
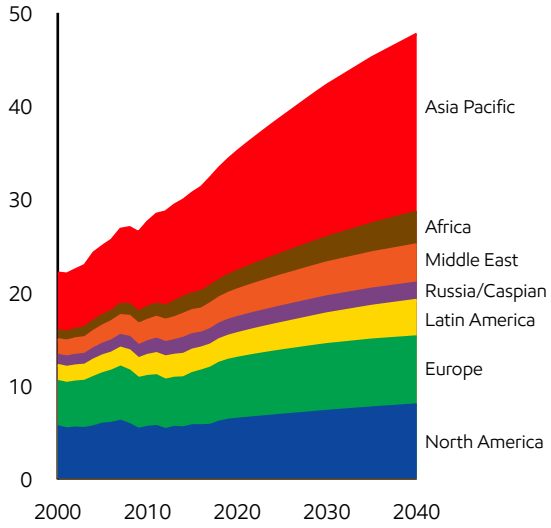
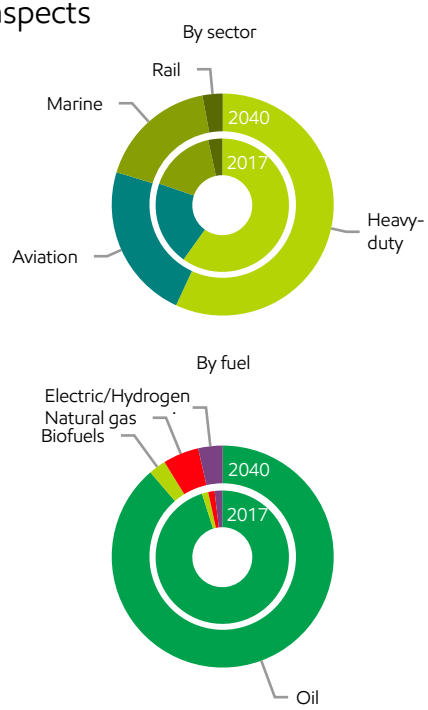


Commercial transportation grows in all aspects

Commercial transportation energy demand – MBDOE



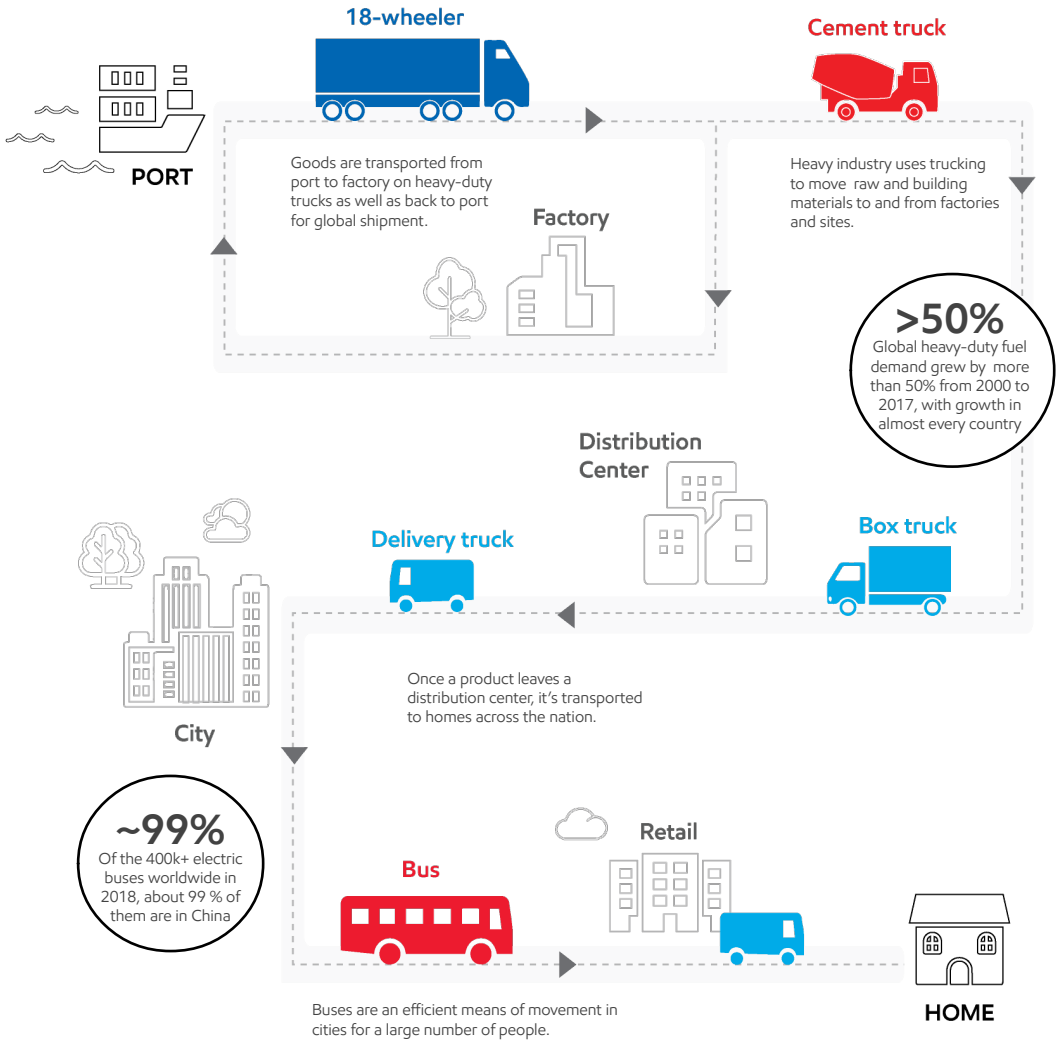


- Historically, commercial transportation services (e.g. ton-miles of freight, passenger-miles of air travel) demand growth tracks with GDP and economic growth
- As GDP continues to grow, especially in developing nations, there will be increased demand for goods and services
- Recent accelerated decoupling of the trends for GDP and commercial transportation demand has been observed and is expected to continue as a result of fuel switching and efficiency improvements (e.g., mode shifting, engine improvements or logistical improvements)
- Continued improvements in efficiency will moderate commercial transportation energy demand associated with expanding economic activity.

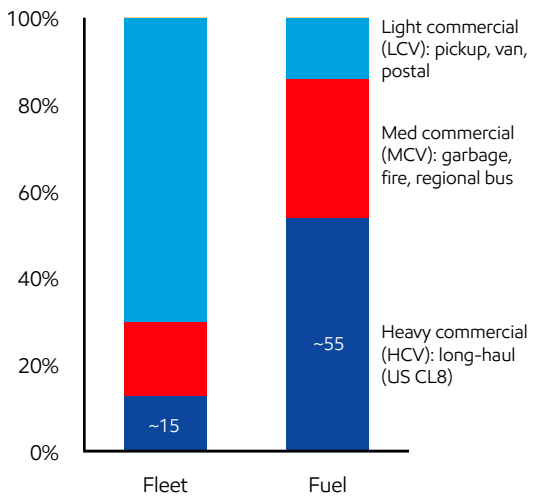
- The largest growth in commercial transportation services is observed in the non-OECD countries, driven by increases in population and GDP
- While all regions see some increased demand, Asia Pacific leads the growth, rising to 40 percent of commercial transportation energy demand
- All modes of commercial transport grow over the *Outlook* period, with heavy-duty trucking accounting for over 50 percent of the growth through 2040
- Electrification plays a role in certain applications (e.g., short-haul trucks and buses), but electricity in commercial transportation grows slowly due to upfront costs, range limitations, payload requirements, and the pace of infrastructure development

TRANSPORTATION — HEAVY-DUTY LANDSCAPE

Heavy-duty transportation demand is driven by economic activity, which leads to increased commerce and movement of goods across oceans, nations, and cities. Fuel demand in this sector is influenced by the type of truck and its use, so understanding fleet dynamics and fuel usage is important for projecting future demand. For example, a light commercial vehicle (LCV) for intra-city deliveries has different energy needs versus a heavy commercial vehicle (HCV) for cross-country shipments of goods. Additionally truck fleets can be quite different from region to region based on the distribution of various sector and economic needs, such as heavy industry, manufacturing or resource extraction.



2015 Heavy-duty fleet/fuel usage mix



Source: IEA The Future of Trucks, 2017, EM analyses

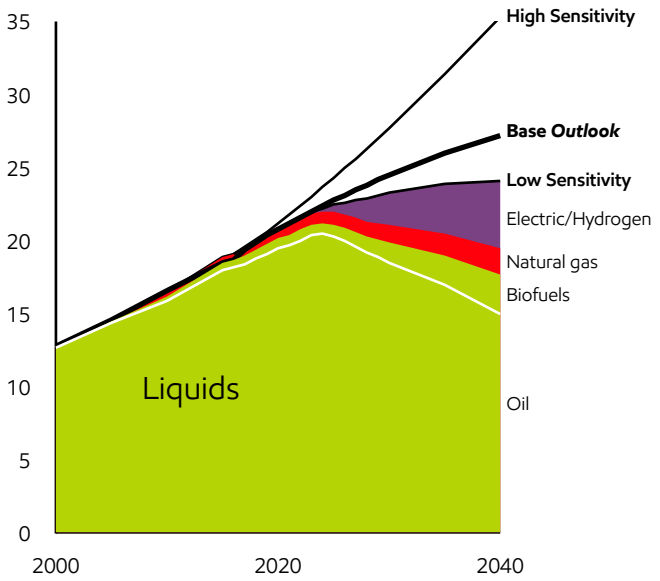
- Fleet breakdown and truck usage play a critical role in understanding the types of alternate fuels available for substitution in trucking
- In 2015, HCV long-haul trucks made up ~15 percent of the fleet, but used ~55 percent of the fuel for trucking driven by the heavy loads carried over long distances

TRANSPORTATION — HEAVY-DUTY SENSITIVITY

We use sensitivity analyses to provide greater perspective on how changes to our base *Outlook* assumptions could affect the energy landscape. Our hypothetical sensitivities explore different fuel efficiency trends in a higher demand case as well as deep penetration of alternatives, such as electricity, biofuels, gas and hydrogen in a lower demand case

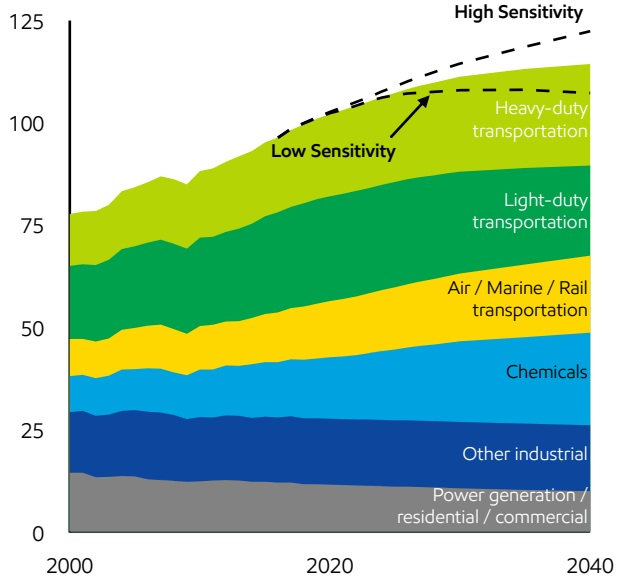
Heavy-duty fuels demand sensitivities

World – MBDOE



Liquids demand sensitivities by sector

World – MBDOE



- The base *Outlook* assumes that future efficiency improves on average at double the historical rate from 2000 - 2016, and that alternative fuels grow to ~13 percent of demand
- In comparison, the high demand sensitivity above assumes future efficiency improves only at the historical rate, which could increase demand ~30 percent versus the base *Outlook*, and highlights the need for continued technology investments in efficiency improvements
- The low demand sensitivity assumes a deeper penetration of alternative fuels with accompanying efficiency gains. The penetration assumptions vary by truck type and usages. LCVs see nearly 100 percent penetration of EVs due to shorter, start/stop routes, MCVs see 70 percent alternative fuels, and HCVs see ~20 percent alternatives, mostly biofuels due to the need for high energy density fuels in long-haul trucks. This sensitivity would require a rapid acceleration in the early 2020s of both alternate fuels into the heavy-duty fleet as well as infrastructure build-out to support the alternatives. The resulting fuel penetration is ~3x the base *Outlook* in 2040, with traditional fuel demand peaking prior to 2025 before declining to mid-2000s levels
- The impact on total liquids demand from the high sensitivity shows liquids demand could be ~7 percent above the base *Outlook*, while in the low demand sensitivity total liquids demand could peak in the mid-2030s as growth in chemicals, aviation and marine are offset by the heavy-duty decline
- These hypothetical sensitivities highlight the difficulty of decarbonizing heavy-duty transportation and the need for further technology development on economic, lower-carbon solutions

RESIDENTIAL AND COMMERCIAL — PROJECTIONS

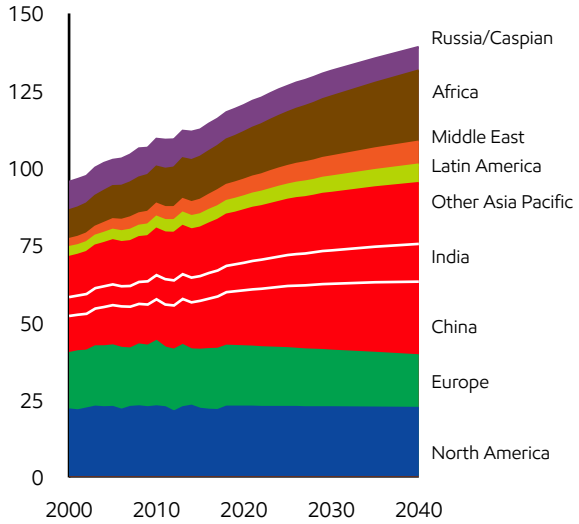
As populations grow and prosperity rises, more energy will be needed to power homes, offices, schools, shopping centers and hospitals.

Combined residential and commercial energy demand is projected to rise by around 20 percent through 2040. Led by the growing economies of non-OECD nations, average worldwide household electricity use will rise about 25 percent between 2017 and 2040.

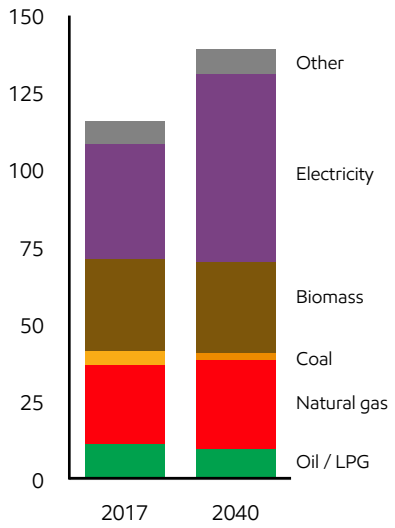
Energy efficiency plays a big role in constraining energy demand growth within the residential and commercial sectors as modern appliances, advanced materials and policies shape the future.

Demand shifts to non-OECD with growth primarily supplied by electricity

Demand by region – quadrillion BTUs



World mix – quadrillion BTUs

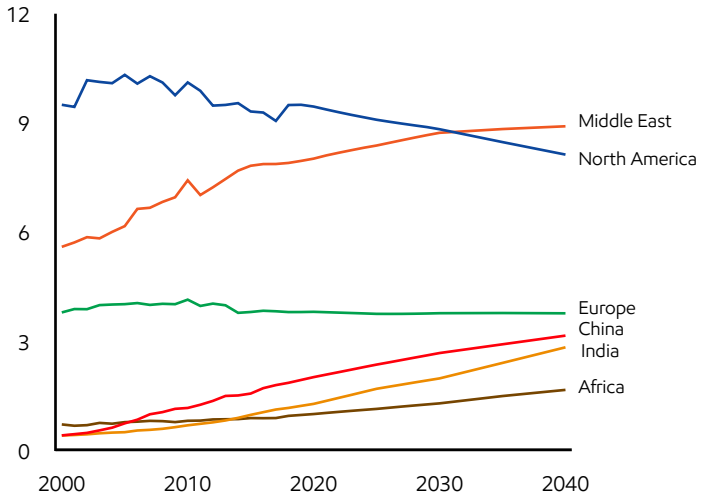


- In addition to the energy people need to heat or cool their homes and keep appliances running, this sector also includes the energy required in hospitals, schools, grocery stores, retail shops, offices, sports facilities and cultural centers
- With rising prosperity and expanding commercial activity comes an increased demand for lighting, heating, cooling and power in homes and offices of around 20 percent by 2040
- Strong middle-class growth in non-OECD nations increases energy demand by more than 35 percent. Improving building efficiencies lower energy demand in OECD countries by about 5 percent
- Globally, electricity supplies the entire net demand increase

RESIDENTIAL AND COMMERCIAL — PROJECTIONS

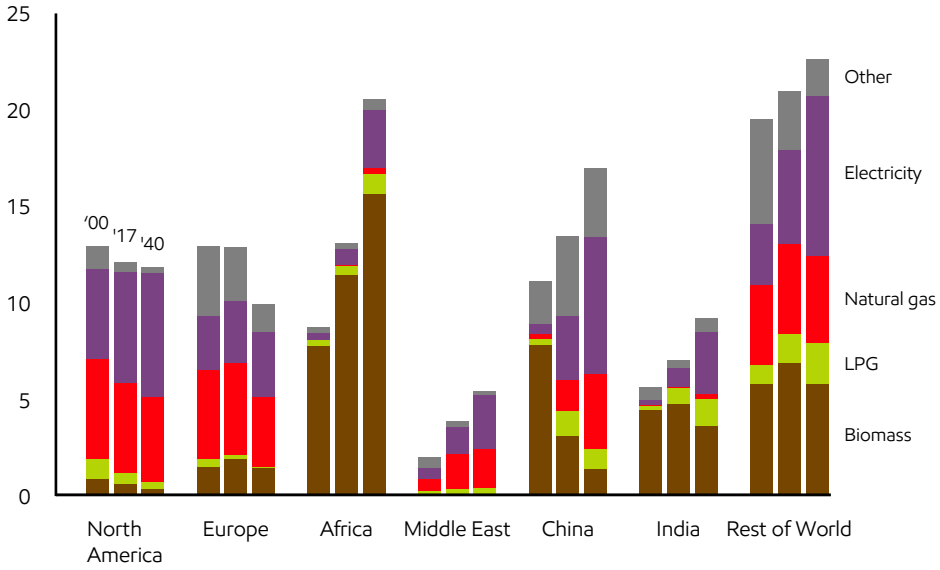
Household electricity up in non-OECD

Residential electricity intensity
Megawatt hours per household per year



Residential energy fuel use varies across regions

Quadrillion BTUs



- Residential electricity use is expected to rise about two-thirds by 2040 as a substantially increased middle class seeks to improve health, security and comfort at home
- The annual electricity use per household in non-OECD countries rises about 60 percent with residential electricity use in India and China expected to grow strongly, bringing electricity consumption per household close to the European average by 2040
- Electricity use per household in OECD nations will be stagnant or declining as more efficient appliances help limit electricity requirements

- Efficient buildings, appliances and consumer products lead to a decrease of residential demand in North America and Europe increasingly met by electricity
- More households, urbanization and rising living standards in developing nations lead to continued energy increases
- While most developing nations transition away from traditional biomass (such as wood and charcoal) with improved access to LPG, electricity and gas, Africa's rising population and insufficient supplies of alternative sources increase its biomass use

INDUSTRIAL — PROJECTIONS

Almost half of the world's energy use is dedicated to industrial activity

As the global middle class continues to grow, demand for durable products, appliances and consumable goods will increase. Without exception, industrial activities are required to manufacture these products and their components. Industrial activities, such as textile manufacture, car assembly or creation of construction materials, take place in almost all regions, and for all this activity energy is required.

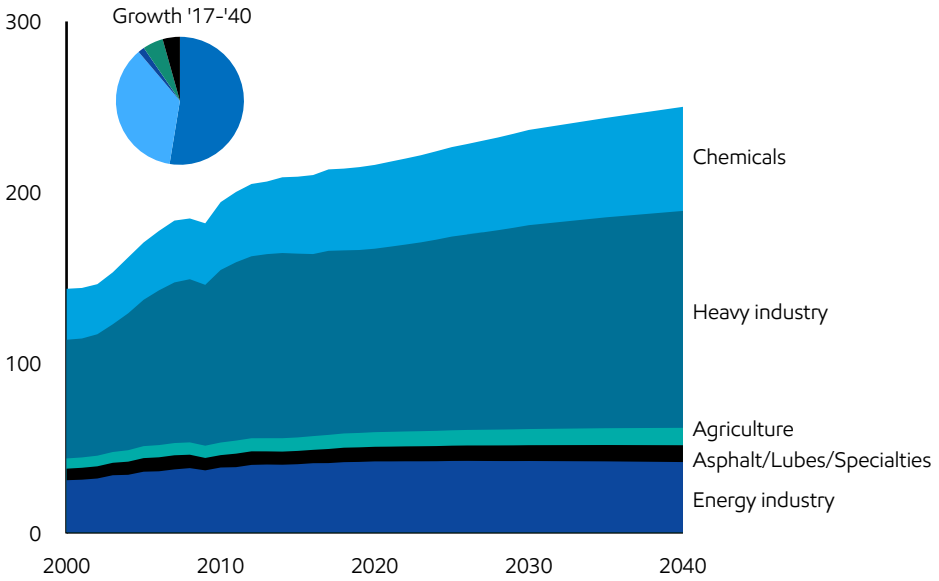
Industry grows in emerging markets, like India, Southeast Asia, the Middle East and Africa. Industry also evolves in OECD nations as businesses and consumers strive to reduce their environmental impact by using energy more efficiently.

Industrial growth takes energy. It also takes innovation. This *Outlook* anticipates technology advances, as well as the increasing shift toward cleaner sources of energy such as electricity and natural gas. The industry of the future will be more energy efficient and less carbon intensive than it is today.

INDUSTRIAL – PROJECTIONS

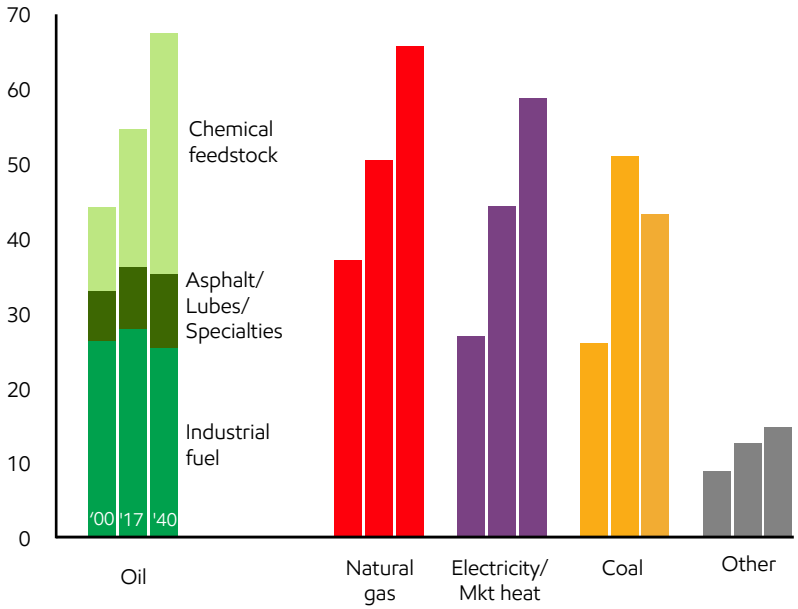
Industrial sector energy supports economic progress

World – quadrillion BTUs



Oil, gas and electricity fuel industrial growth

World – quadrillion BTUs



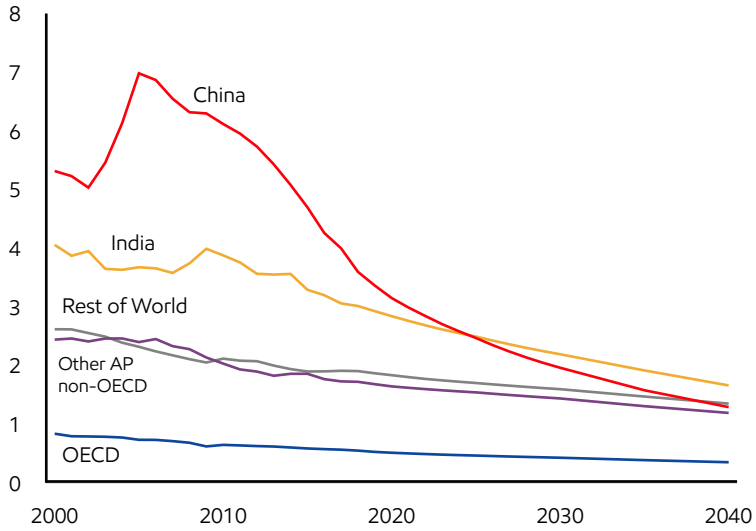
- The industrial sector provides more than a billion jobs for people who work to feed, clothe, shelter and improve the lives of people around the world
- Rising population and prosperity trigger demand for modern cities, medical equipment, mobility and home appliances that underpin the need for steel, cement and chemicals
- In 2017, the industrial sector used about half the world's electricity and nearly as much primary energy as the transportation and residential/commercial sectors combined
- Increased options for consumers to 'reduce, reuse, recycle' and manufacturers' efforts to improve industrial processes and efficiency can conserve fuel and mitigate emissions
- Heavy industry (steel, cement, metals and manufacturing) and chemicals (plastics, fertilizer and other chemical products) are expected to account for 85 percent of growth to 2040

- Industry uses energy products both as a fuel and as a feedstock for chemicals, asphalt lubricants, waxes and other specialty products
- Oil, natural gas and electricity each contribute about one-third of industrial energy growth to 2040
- Oil grows because it is particularly well-suited as a feedstock; companies choose natural gas and electricity for their versatility, convenience and lower direct emissions
- Coal is expected to continue to play a role in steel and cement manufacturing but its use declines as nations and businesses strive to reduce their environmental impact
- Shifting to lower-carbon fuels holds the industrial sector's 2040 direct emissions at about the same level as 2017 even as energy demand increases by around 15 percent

INDUSTRIAL – HEAVY INDUSTRY PROJECTIONS

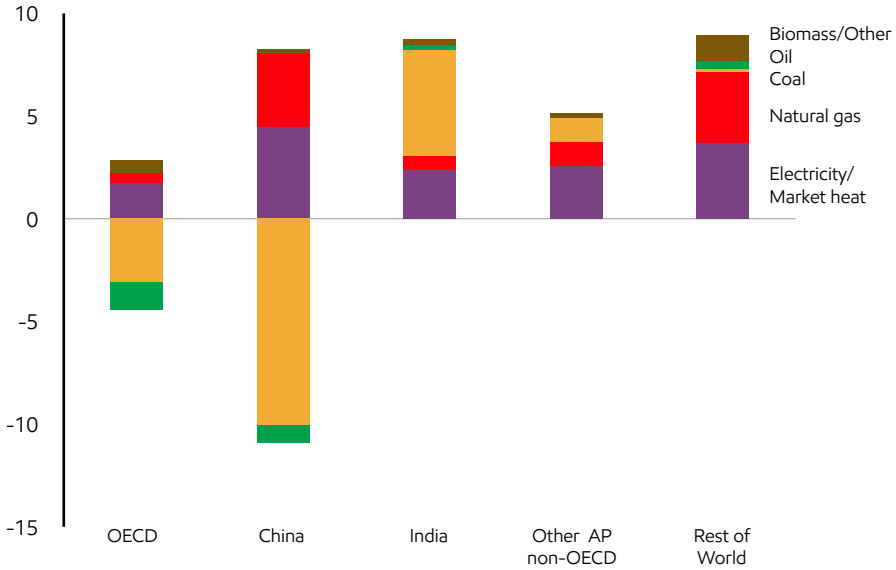
Heavy industry energy intensity improves

Thousand BTUs per dollar of GDP



Heavy industry transitions toward cleaner fuels

2017-2040 change in quadrillion BTUs



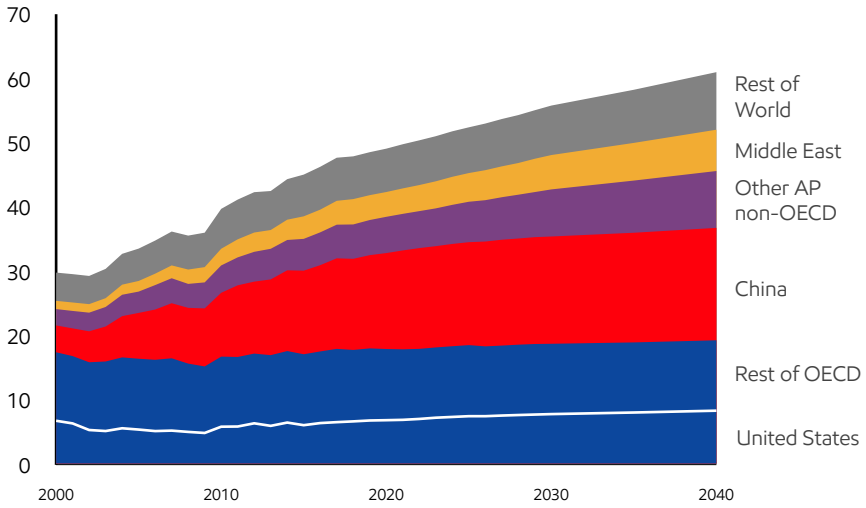
- Heavy industry energy intensity measures the amount of energy used in heavy industry and manufacturing per dollar of overall economic activity (GDP)
- Producing more value with less energy has a positive impact - economically and environmentally - for manufacturing companies and countries
- OECD nations have lower energy intensity due to their service-based economies and predominance of higher-value, energy-efficient industries
- China's intensity spiked as it invested in infrastructure and heavy industry; recently its intensity has been improving rapidly as its economy matures and efficiency increases
- Optimizing energy use via advances in technology, processes and logistics can help companies remain competitive and contribute to gains in global energy-intensity

- Manufacturing tends to gravitate toward regions with access to abundant, affordable energy, an able workforce and balanced policies
- Each region's fuel mix differs based upon its unique blend of manufacturing activity and the relative availability and cost of its energy sources
- Electricity use is expected to grow; it is ideal for motors, robotics and process controls
- Natural gas is expected to give a competitive edge to resource-rich areas of Africa, the Middle East and Latin America; it also helps China manage its air quality
- Coal's use declines in the OECD and China but doubles in coal-producing India and the rest of Asia because of coal's abundance and affordability relative to other fuels

INDUSTRIAL – CHEMICAL PROJECTIONS

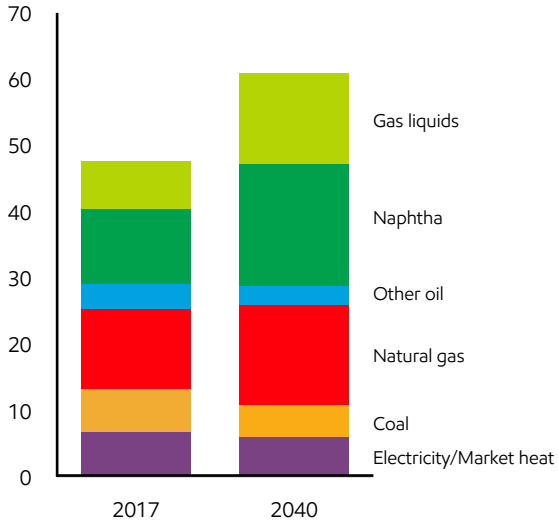
Consumer demand boosts chemicals energy growth

Quadrillion BTUs



Chemicals production relies on oil and natural gas

World – quadrillion BTUs



- Chemicals are the building blocks for a wide variety of products people rely on every day
- Demand for fertilizer, adhesives, cosmetics, textiles and plastics used in medical devices, cars, computers and other basic home goods spur chemicals growth
- Asia Pacific's chemicals production grows to meet the needs of its rising middle class
- Investors in the U.S. and Middle East chemicals production are expected to tap abundant, affordable energy supplies (used as feedstock and fuel) to gain competitive advantage
- Europe, Russia, South Korea and Japan remain important contributors to global chemicals production

- The chemical industry uses hydrocarbon products as both a feedstock and a fuel
- 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 almost doubles from 2017 to 2040, as unconventional oil and natural gas production in the United States expands supply
- Naphtha is expected to remain the dominant feedstock in Asia; the Middle East is expected to rely on natural gas liquids and natural gas
- Advances in plastic materials and chemical processes can save energy as the industry continues to meet rising consumer demand for high-performing products

ELECTRICITY AND POWER GENERATION — PROJECTIONS

Global electricity demand rises 60 percent

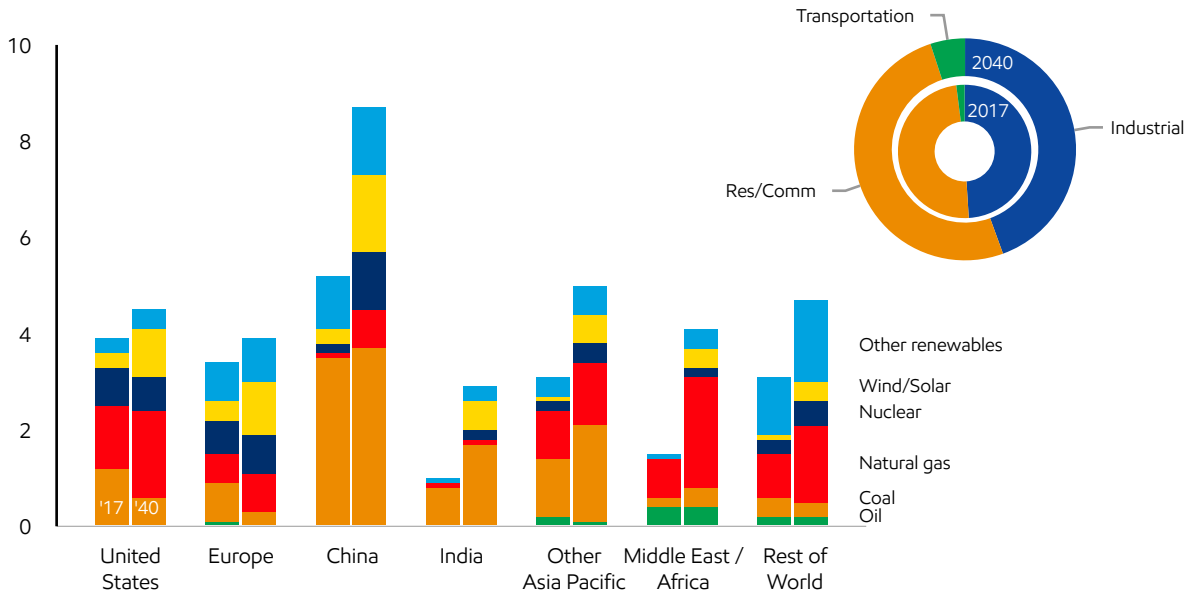
Since it first started lighting homes in the late 1800s, electricity has provided the means to boost economic productivity and improve the human condition with modern conveniences like electric motors, air conditioning and refrigeration. Power generation has witnessed transitions in fuel sources from coal to nuclear and gas, and now we are harnessing wind and solar energy. The growth of new energy sources is impacted by factors such as technology cost improvements, the availability and quality of domestic resources, and government policies.

Electricity demand is expected to grow around the globe, supplied primarily by growth in wind, solar, natural gas-fired generation and nuclear. Besides meeting residential, commercial, and industrial demand, the increase in electricity demand is also fueled by the growth of electric vehicles in light-duty transportation. Cost reductions in transportation batteries are being leveraged for other applications including larger-scale electricity storage.

Today, batteries represent a small share of installed capacity on the grid, and are used for short-duration storage. The increased variable production from weather-dependent wind and solar triggers additional transmission build-out, storage and flexible gas peaking generation but results in reduced asset efficiency. Further breakthroughs that provide new solutions deployable at commercial scale to maintain reliable and affordable electricity for consumers are needed.

Electricity generation highlights regional diversity

Net delivered electricity – thousand TWh

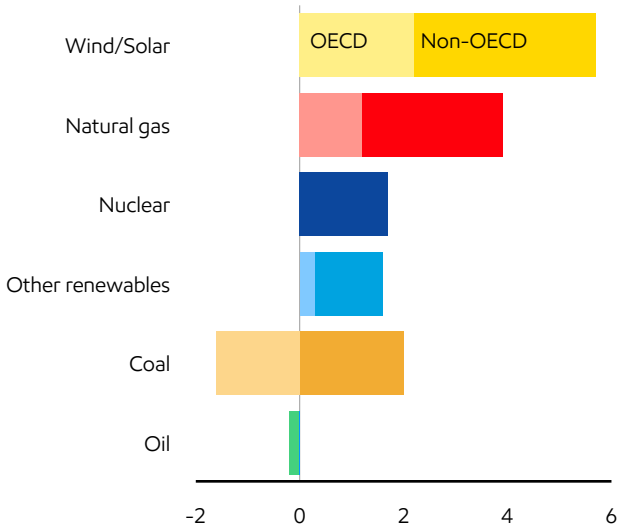


- The mix of electricity generation varies geographically as a result of technology costs, domestic resource availability and policy targets (e.g., renewable portfolio standards for local generation)
- Much of the world continues to shift further to lower-carbon sources for electricity generation, led by wind and solar, natural gas and nuclear, based on local opportunities and policies
- In 2017, coal-fired generation was the leading source of electricity production (accounting for over 45 percent in non-OECD countries). While China's coal-fired electricity remains nearly constant to 2040, its share in power generation decreases as renewables and nuclear provide almost 85 percent of the delivered electricity growth
- The share of electricity use into transportation is small today, but is expected to grow with increasing penetration of electric vehicles as a result of emissions/fuel economy targets and cheaper batteries

ELECTRICITY AND POWER GENERATION – PROJECTIONS

Renewables and natural gas dominate growth

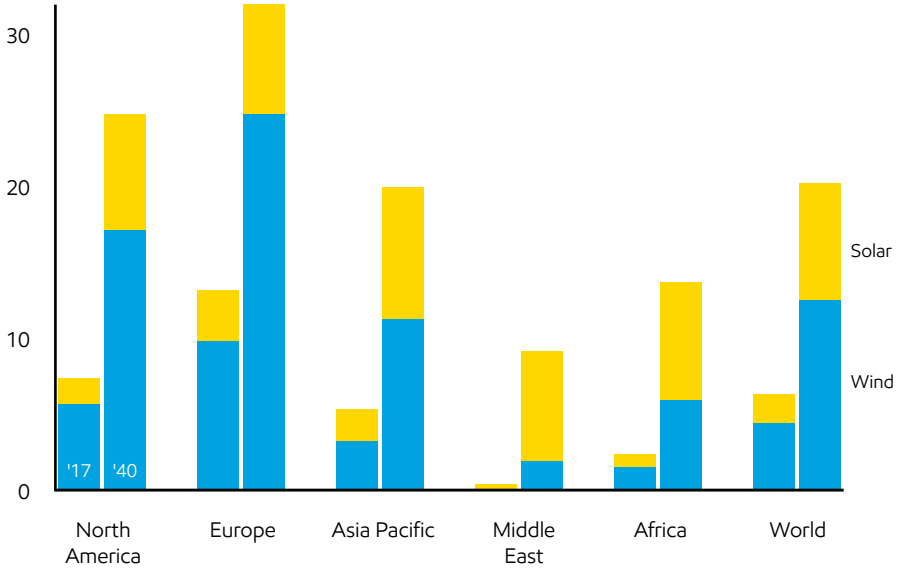
Global growth 2017-2040 – thousand TWh (net delivered)



- Wind and solar generation grow the most to 2040, supported by technology cost reductions (particularly for solar) and policies targeting lower CO_2 emissions
- Natural gas grows significantly; OECD growth is partially due to coal-to-gas switching, while half of the non-OECD growth is in gas-producing Africa and the Middle East
- China accounts for nearly 70 percent of all nuclear growth. OECD growth nets to near zero as expected nuclear restarts in Japan are offset by phase-out of nuclear in other OECD nations due to concerns about costs and safety
- Coal-fired generation grows in the non-OECD, primarily in Asia Pacific countries with domestic resources, growing electricity demand and favorable economics

Renewables penetration increases across all regions

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



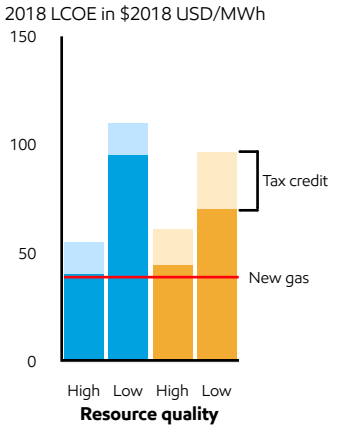
- Wind and solar grow across the globe, but penetration in 2040 varies based on natural resource quality and varying levels of policy support. Globally, wind and solar's share of delivered electricity grows significantly from about 6 percent in 2017 to about 20 percent in 2040
- In 2040, wind and solar are expected to deliver 25 percent or more of electricity in Europe and North America, contributing to renewables policy goals
- Renewables growth in Asia Pacific contributes to local air quality improvements and energy security goals
- Up to 20-30 percent wind and solar penetration can be achieved without significant additional costs to the power grid. Higher penetration levels incur additional costs to manage intermittency through flexible backup generation, transmission build-out and storage to ensure reliable electricity delivery

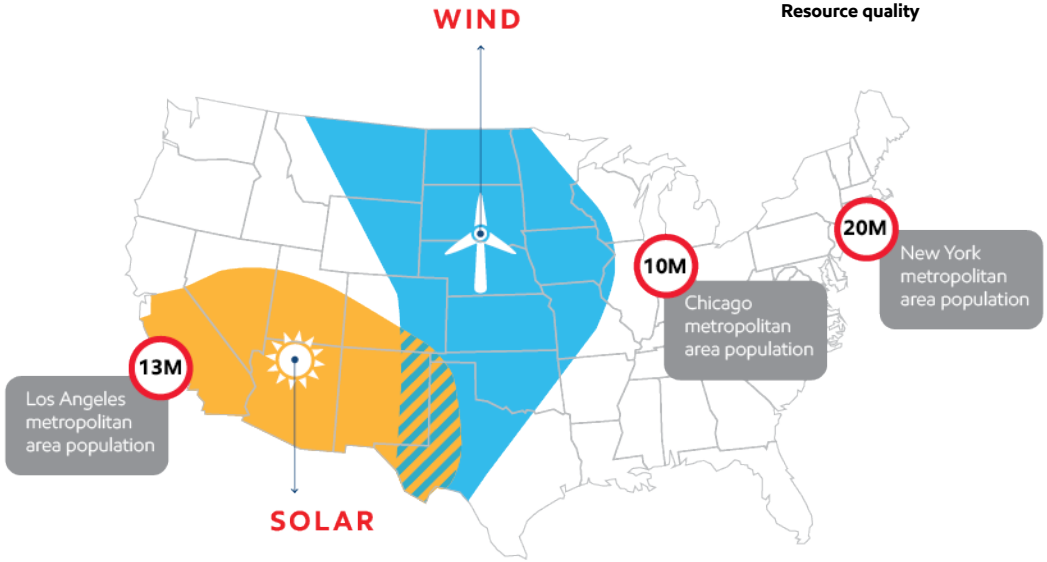
ELECTRICITY AND POWER GENERATION — CONSIDERATIONS

Wind and solar are potential solutions for lower-emission power generation, but the quality of resources varies geographically, even within national borders. These resources are also not always located near high population areas demanding electricity, requiring additional transmission and distribution infrastructure. Technology choices used in power generation can be compared by looking at the cost plus return on capital to generate a unit of electricity, known as the levelized cost of energy (LCOE). This cost is impacted by factors including the cost for the equipment, maintenance, fuel, financing terms and tax incentives. As shown below, resource quality variation can lead to a 2-3 fold increase in cost due to location. Assessing the optimum mix of power generation technologies is a local evaluation because cost factors and policies can vary greatly between sites even within a country.

WIND AND SOLAR IN THE CONTINENTAL US

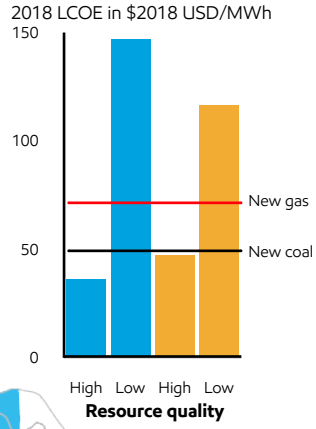
Solar power is best suited in the Southwest region of the United States, while wind power is concentrated in the middle plains. High quality wind and solar resources are cost-competitive against low-price natural gas generation in these parts of the U.S. with support from tax and financing incentives.

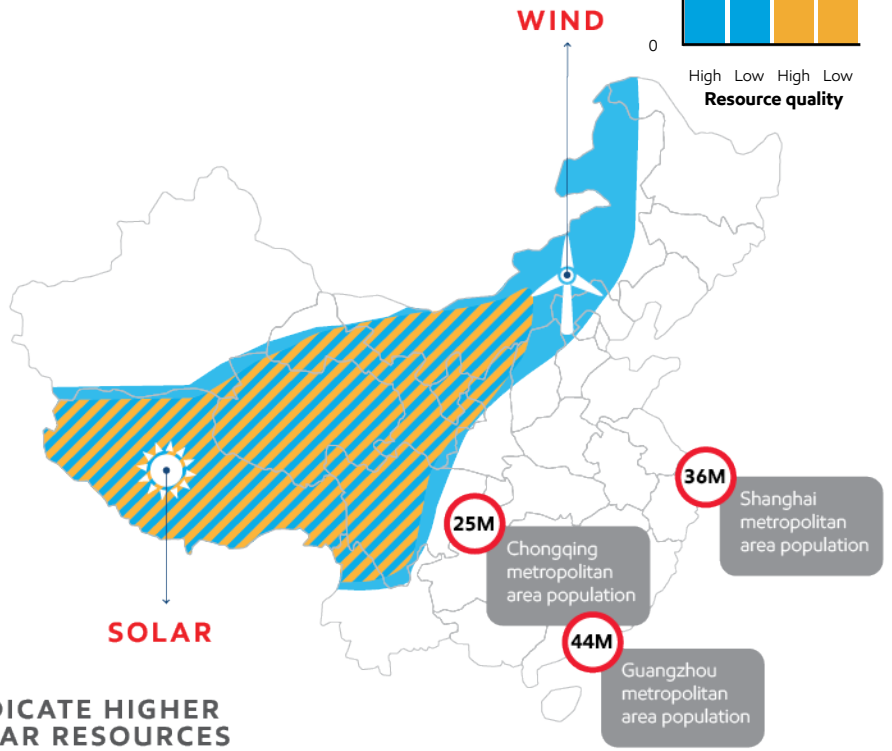




WIND AND SOLAR IN MAINLAND CHINA

China's build-out of long-distance transmission is connecting high resource wind and solar renewables in the northwest to high population centers.High quality wind and solar resources are competitive versus imported natural gas, while coal remains a low-cost option but has challenges with air quality impacts.





SHADED AREAS INDICATE HIGHER QUALITY WIND/SOLAR RESOURCES

ELECTRICITY AND POWER GENERATION — NATURAL GAS SENSITIVITY

Similar to the transportation sector, we use sensitivity analyses to provide greater perspective on how changes to our base *Outlook* assumptions in the power generation sector could affect the energy landscape.

Power generation modeling is complex with a number of questions to explore for both demand growth and supply mix, including:

- How will electricity access expand in developing nations?
- How will technology evolve to enable more electricity use in other sectors (e.g., EVs for personal mobility instead of gasoline-fueled cars or mass transit)?
- How will developing nations transition off coal if it is their lowest cost supply today?
- Will perceptions about nuclear safety challenge new builds in some countries?
- What is the optimum penetration of variable renewables before intermittency challenges create reliability and cost impacts for power grids?

There are a number of different potential outcomes for each of these questions that could yield different projections. The top chart shows outcomes for different third-party models, including some deep decarbonization scenarios like the IEA's Sustainable Development Scenario (IEA SDS). These results describe a range of potential outcomes with some common trends:

- Electricity demand grows significantly from today to 2040
- Zero-carbon power generation grows 2-3x due to cost competitiveness and policies
- Gas use for electricity grows in all cases except the IEA SDS, accompanied with coal's decline primarily in developed countries

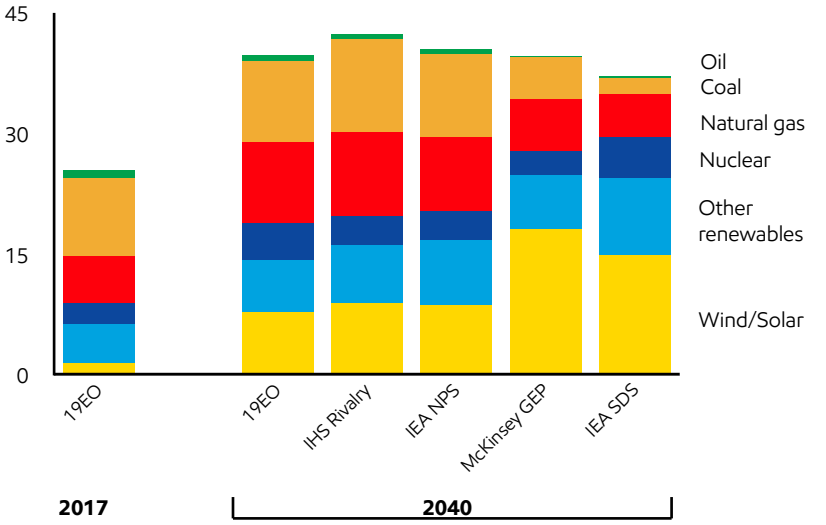
The bottom chart is a sensitivity to test the impact of alternate assumptions on natural gas:

- Lower cost wind and solar with efficient storage to manage their inherently variable production could increase penetration to 50 percent of supply (more than 2x the base *Outlook*). Ratable reductions in both coal and natural gas by region could reduce global natural gas demand by ~115 BCFD
- Decline in coal-fired generation occurs predominantly in developed countries out to 2040. Switching 50 percent of the remaining coal to natural gas to address issues such as air quality and emissions could increase natural gas demand by over 20 percent

Monitoring technology advancements, market behavior and the evolving policy landscapes can identify signposts related to cost reduction, technology deployment and policy targets indicating how a different outcome may materialize.

Views of the electricity supply mix vary based on assumptions

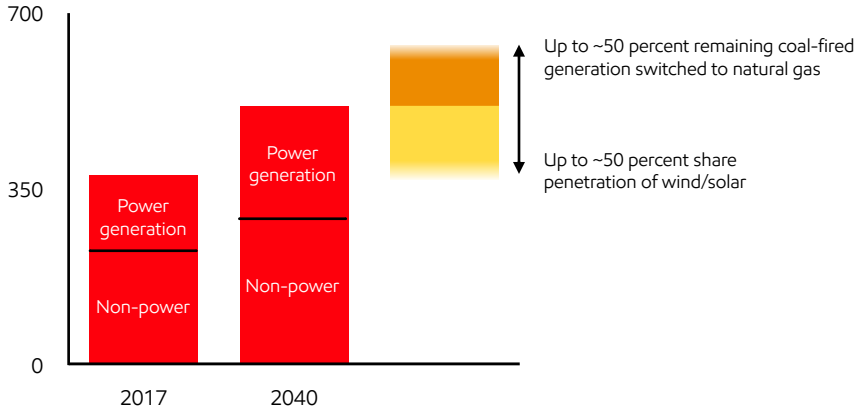
Supply of electricity - Thousand TWh



Source: IHS Markit, IEA World Energy Outlook 2018, McKinsey

Different policy or technology choices can impact gas demand

Global natural gas demand sensitivity – BCFD



Natural gas volume represents both power generation and non-power sector demand
Shaded ranges are indicative of potential shifts in demand relative to base *Outlook*

SUPPLY — PROJECTIONS

Energy - in all its forms - enables growth and prosperity. As economies grow, as technology advances, as consumers become more environmentally aware and as policies adapt, global energy demand will evolve to meet changing needs.

The supply mix to meet rising consumer demand will be increasingly diverse, leveraging a wide range of economic energy sources. Renewables - wind, solar, biofuels, hydro and geothermal energy - together with carbon-free nuclear energy are expected to grow at the fastest pace. Oil and natural gas (and even coal) continue to play a significant role in providing reliable, affordable energy the world needs to sustain global economic progress.

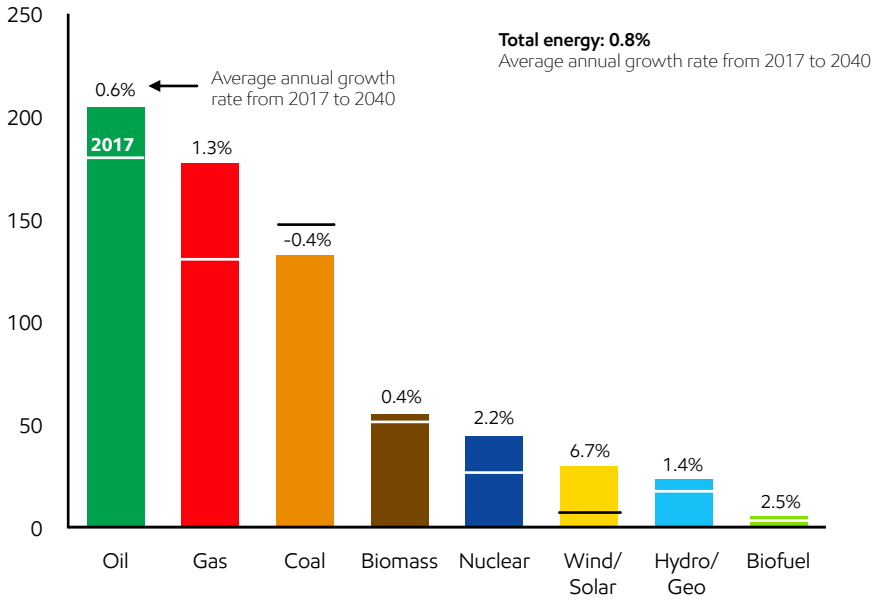
From the industrial revolution to the shale revolution and the rise of modern renewables, innovators, engineers and entrepreneurs have tackled tough challenges to unlock new energy sources - and we expect they will continue to do so.

Projected share of 2040 energy

SUPPLY — PROJECTIONS

Energy supply evolves to meet demand projections

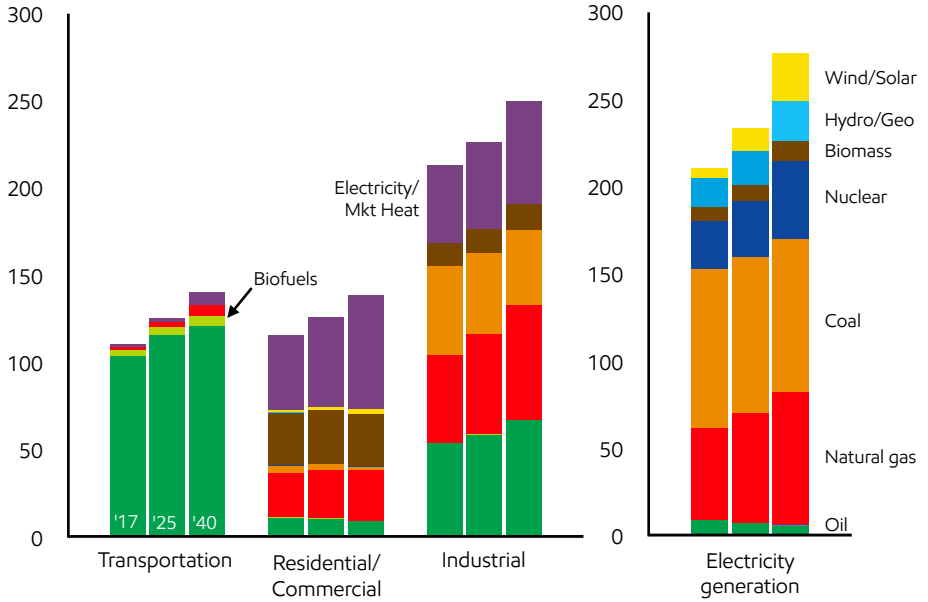
2040 global demand by fuel – quadrillion BTUs



Global energy supplies vary by sector

End-use energy - quadrillion BTUs

Primary energy - quadrillion BTUs



- Technology improvements help achieve more efficient fuel use and lower emissions intensity across all sources of supply
- Oil remains the largest source; essential for commercial transportation and chemicals
- Natural gas demand rises the most, largely to help meet increasing needs for electricity and lower-carbon industrial heat
- Lower carbon energy sources - including wind/solar, biofuels and nuclear - increase at the fastest pace
- Coal is still prominent in some non-OECD countries, however global consumption likely peaked in 2013, as the OECD and China shift to lower-carbon energy sources

- The energy mix to meet rising demand - while also addressing environmental impacts, including the risks of climate change - will vary by sector
- Oil remains essential for transportation, where growing commercial transportation still relies on liquid fuels to meet more than 90 percent of demand
- With a drive for cleaner and more efficient operations, the industrial sector relies primarily on electricity and natural gas for growth; industrial oil demand grows as a feedstock for chemicals, asphalt, lubricants and other specialty products
- Electricity demand rises in all end-use sectors while the mix of fuel supply for electricity generation is shifting to lower-carbon sources

LIQUIDS — PROJECTIONS

Liquids are projected to remain the world's leading energy source in 2040, even as demand growth slows beyond 2030.

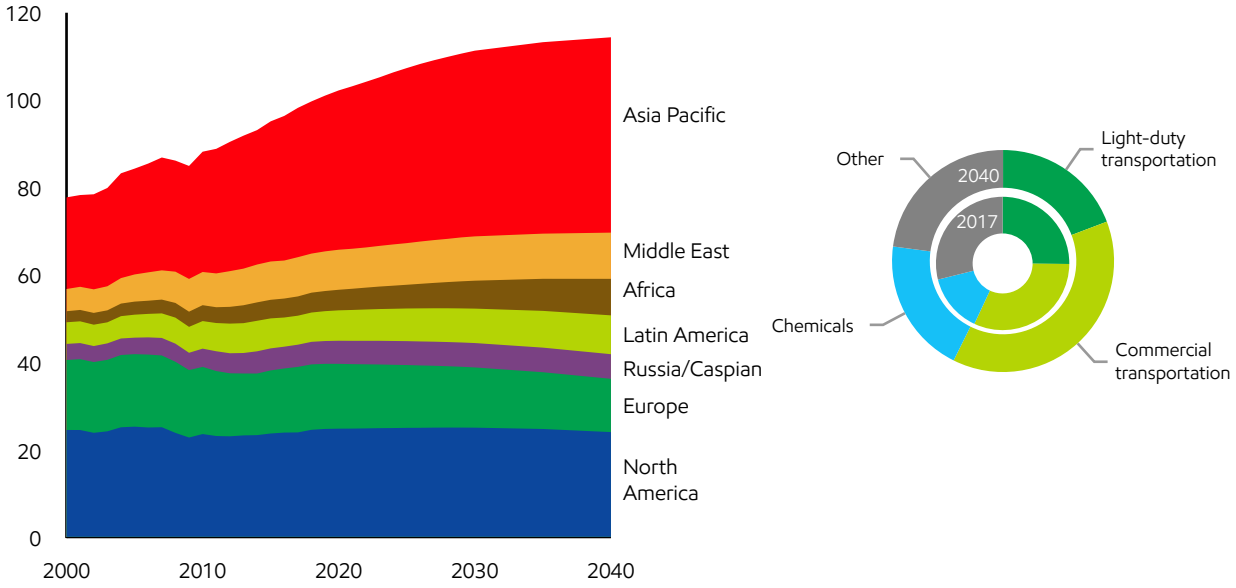
Commercial transportation and chemicals - sectors where liquid fuels are favored for their high energy density and distinctive chemical properties - drive liquids demand growth. Overall, demand for liquids is expected to rise about 16 million barrels per day by 2040 with almost all of the growth in the emerging markets of Asia, Africa, the Middle East and Latin America.

New investments in oil production - and in technologies to improve recoverability, enhance efficiency and reduce cost - are needed to offset natural production decline and meet rising demand. Much of the growth in liquids production is expected to be from sources of supply that have been unlocked by technology advances in the past two decades: North American tight oil and the natural gas liquids associated with unconventional oil and gas production, deepwater projects offshore Brazil and Guyana, and Canadian oil sands, for example.

Continued investment in conventional crude and condensate is required too as the Middle East and Russia/Caspian remain significant oil producing regions helping meet the needs of consumers worldwide.

Liquids demand driven by transportation and chemicals

By region and sector – MBDOE

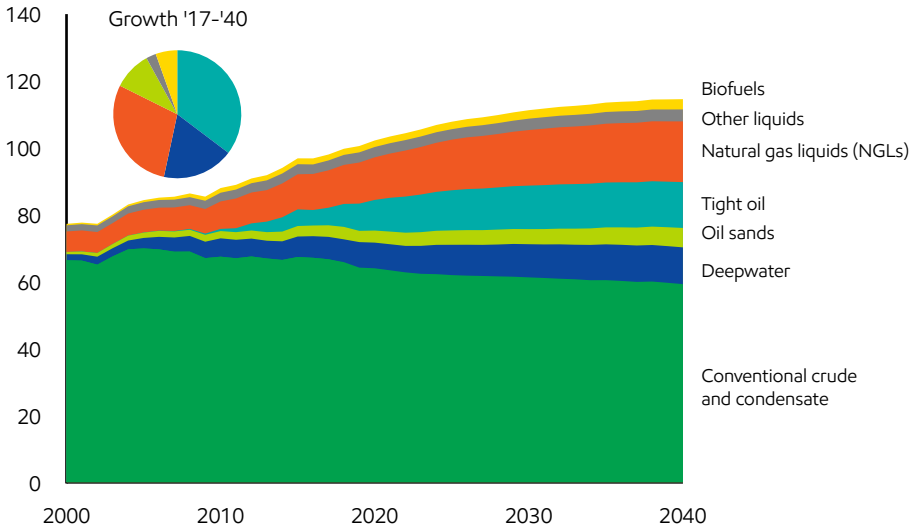


- Global liquids demand growth is concentrated in developing nations, with Asia Pacific accounting for about 65 percent of global growth by 2040
- Efficiency gains and fuel switching in Europe reduce liquids demand by about 20 percent from 2017 to 2040, led by a reduction of about 55 percent in light-duty vehicle liquids demand
- Chemicals and commercial transportation sectors make up nearly all of the liquids demand growth, with these sectors growing about 60 percent and 40 percent, respectively to 2040

LIQUIDS – PROJECTIONS

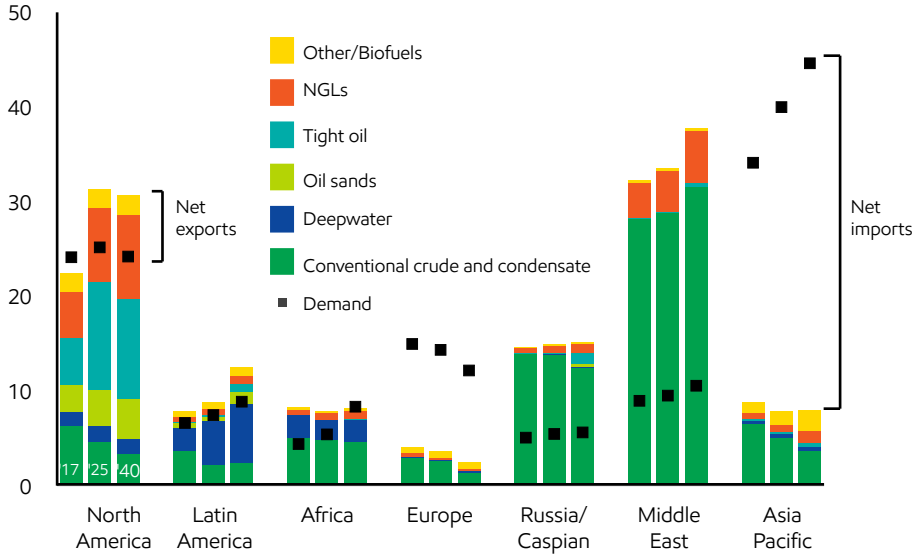
Liquids supply highlights the need for investment

Global liquids supply by type – MBDOE



Liquids supply highlights regional diversity

By region and type – MBDOE



- The supply of existing oil production naturally declines at an estimated 7 percent per year without further investment. Significant investment is needed to offset this natural decline and meet the projected demand growth
- In 2017, conventional crude and condensate made up about two-thirds of the liquid supply. By 2040, new investment is expected to have diversified oil supply such that only about half of liquids will come from these conventional sources
- Tight oil is also rich in Natural Gas Liquids (NGLs), so tight oil growth brings significant new supplies of NGLs
- Biofuels grow more than 70 percent with increasing demand for lower-carbon liquid fuels and technology advancements that reduce costs and land-use

- North America tight oil and associated NGLs production nearly doubles between 2017 and 2025. This significant growth swings North America to a net exporter of liquids
- After 2025, new deepwater supplies from Latin America and conventional crude from the Middle East grow to meet global demand
- The Middle East and Russia/Caspian will continue to invest in conventional oil production to maintain their role as leading exporters, at about two-thirds of their production in 2040
- Asia Pacific remains the largest and fastest growing region for liquids demand, and relies on increasing imports to supply the strong demand

NATURAL GAS — PROJECTIONS

Natural gas plays a vital role in satisfying the energy needs of consumers worldwide while helping to mitigate the risks of climate change.

Choosing natural gas as a cleaner-burning alternative to coal improves air quality and reduces carbon intensity.

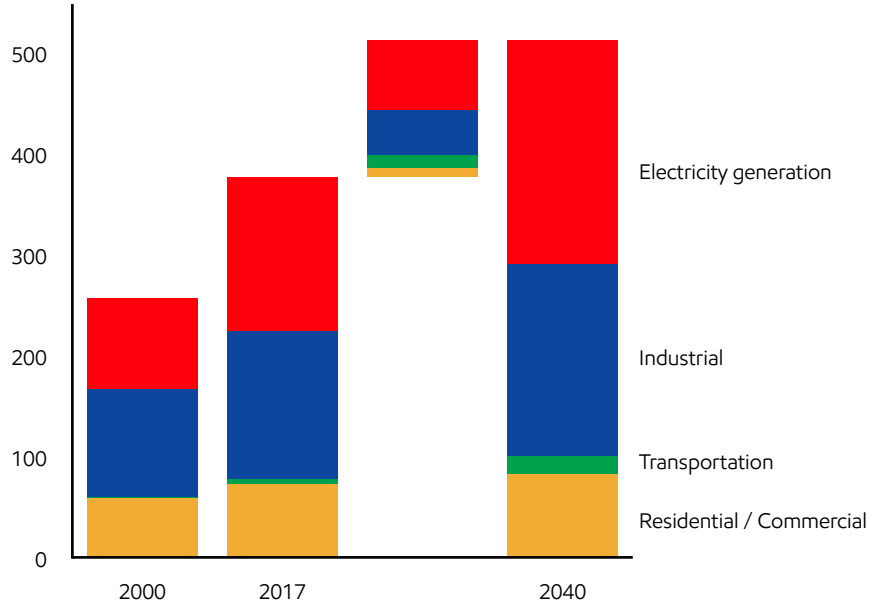
Natural gas is abundant and versatile. It is a reliable and flexible fuel for electricity generation, a cleaner industrial fuel and convenient for home use. Natural gas grows more than any other energy source, rising from 23 percent of global energy supply in 2017 to 26 percent in 2040.

Natural gas resources are geographically and geologically diverse. North America's unconventional gas resources are produced by applying horizontal drilling and hydraulic fracturing technologies. The Middle East and Africa are expected to tap large conventional natural gas resources. Natural gas production is expected to grow in every region except Europe.

Natural gas trade is a critical link between resource-rich regions and demand centers in Asia Pacific and Europe. New liquefied natural gas export projects are expected to diversify the market and meet 40 percent of the growth in natural gas demand to 2040.

Reliable natural gas grows in every sector

World – BCFD

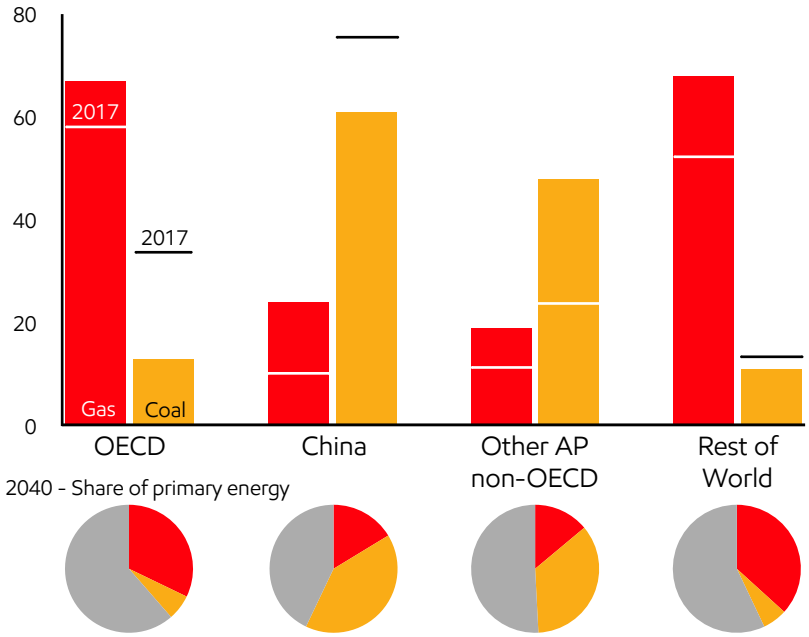


- Natural gas is well-suited for homes, businesses and electric utilities seeking versatile, cleaner-burning energy
- Abundant and convenient, natural gas grows more than any other source of primary energy during the *Outlook* period
- Half of the growth in natural gas demand is for electricity generation and one-third is for industrial use
- Residential users rely on natural gas for heating and cooking
- Increased penetration of natural gas-fueled buses and trucks can help urban areas manage air quality

NATURAL GAS — PROJECTIONS

Natural gas is growing, but coal is still predominant in non-OECD Asia

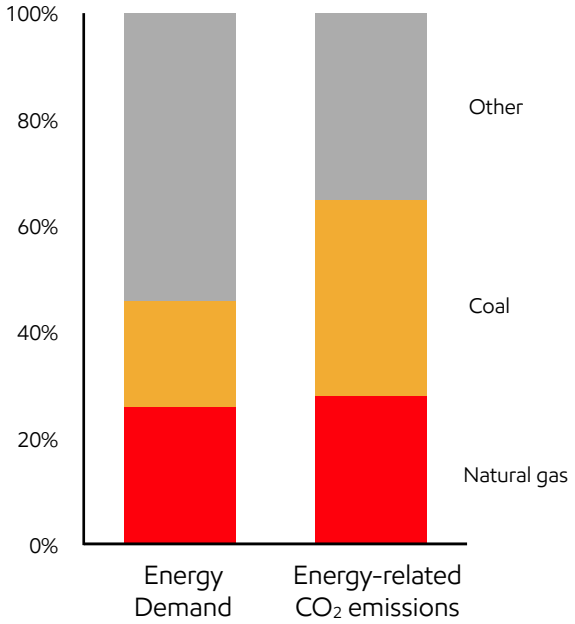
2040 - Quadrillion BTUs



- Natural gas rises in prominence as a cleaner burning alternative to coal over the *Outlook* period
- In China and Other AP non-OECD together, gas demand more than doubles from 2017 to 2040, but coal still plays a significant role in the region
- Coal demand doubles in Other AP non-OECD, partially offsetting major strides to reduce the use of coal in the OECD and China
- Outside of Asia Pacific, many developing countries are expected to leverage domestic natural gas supplies to meet rising electricity demand and fuel industrial growth

Coal-to-natural gas switching reduces emissions

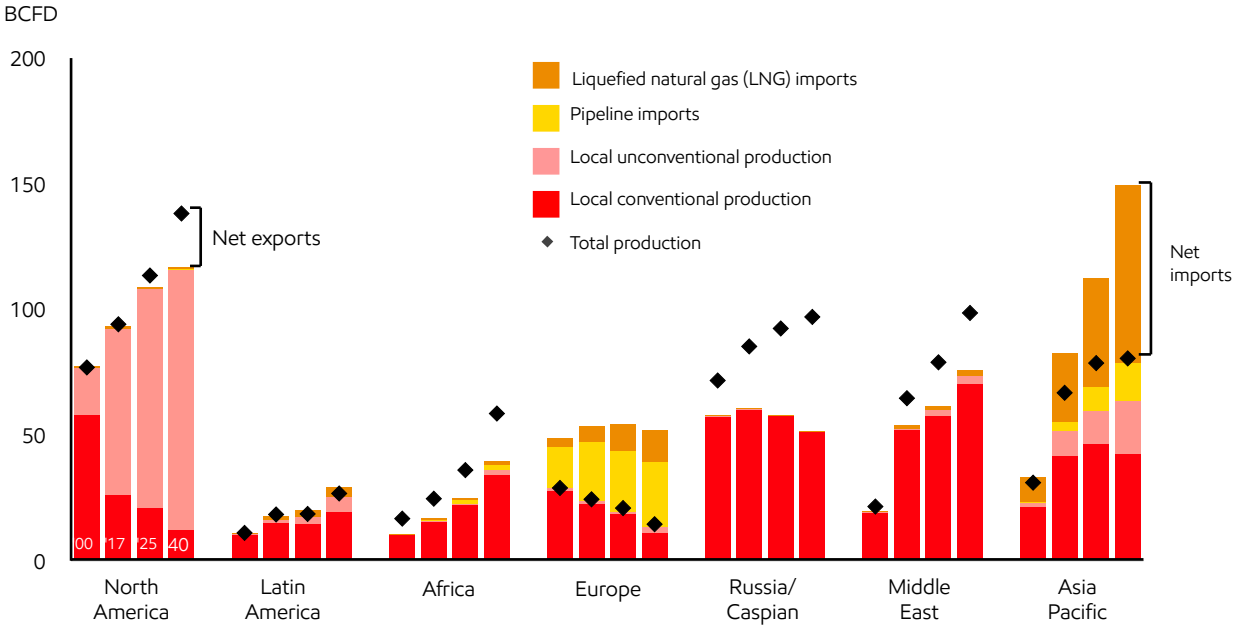
2040 - Global share



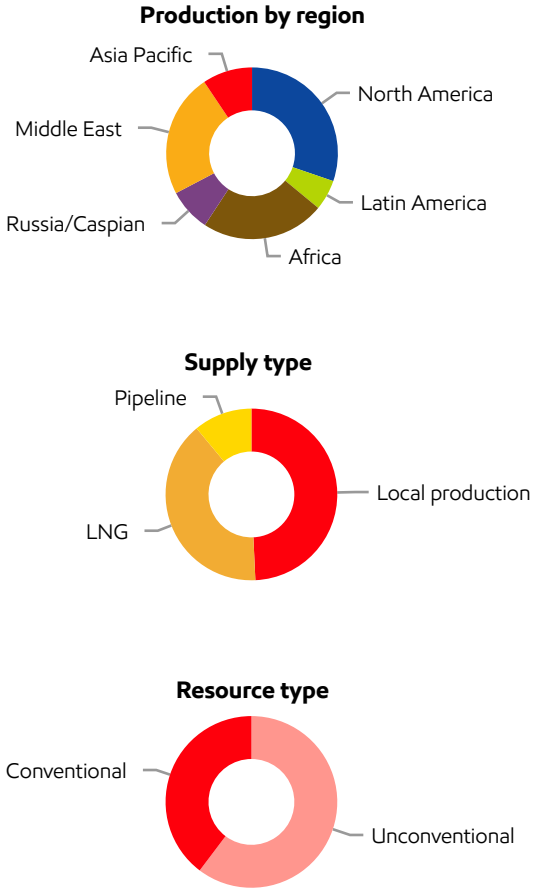
- In 2040, coal is expected to meet just 20 percent of global energy demand but produce more than 35 percent of energy-related CO_2 emissions
- With the same boiler efficiency, burning natural gas to produce heat emits about 40 percent less CO_2 than burning coal
- Choosing flexible, highly efficient gas-fired electricity generation to replace older, inefficient coal plants can reduce CO_2 emissions by up to 60 percent while also producing fewer air pollutants
- Every 1 percent of global primary energy shifted from coal to natural gas can reduce energy-related CO_2 emissions by nearly 1 percent in 2040

NATURAL GAS — PROJECTIONS

Gas supply diversifies and trade grows to meet rising demand



Share of supply growth 2017-2040

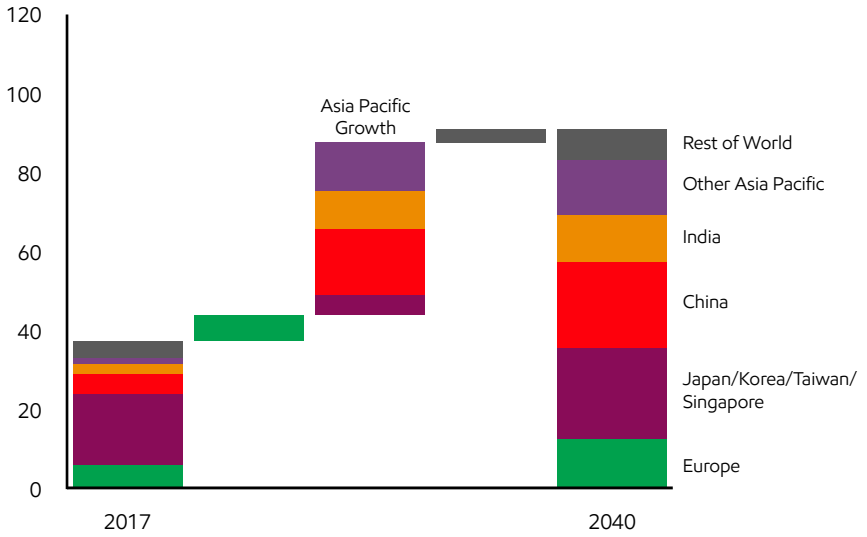


- Rising global demand, competitive new projects in diverse locations and robust trade will shape future natural gas supplies
- North America's abundant unconventional gas is expected to feed new LNG projects and meet growing local demand
- Africa's natural gas production, demand and exports are poised to accelerate, led by Mozambique, Nigeria and Egypt
- Russia/Caspian and the Middle East together are anticipated to retain more than half of inter-regional gas trade by further investing in export projects; both regions are well positioned to expand pipeline exports in addition to LNG trade
- Europe is likely to increasingly rely on natural gas trade to meet consumer demand as local production declines
- In 2017, Asia Pacific's natural gas imports rivaled Europe's; by 2025, the region's total natural gas demand will likely surpass North America's; and in 2040, LNG trade is expected to meet nearly half of Asia Pacific's natural gas demand

NATURAL GAS – PROJECTIONS

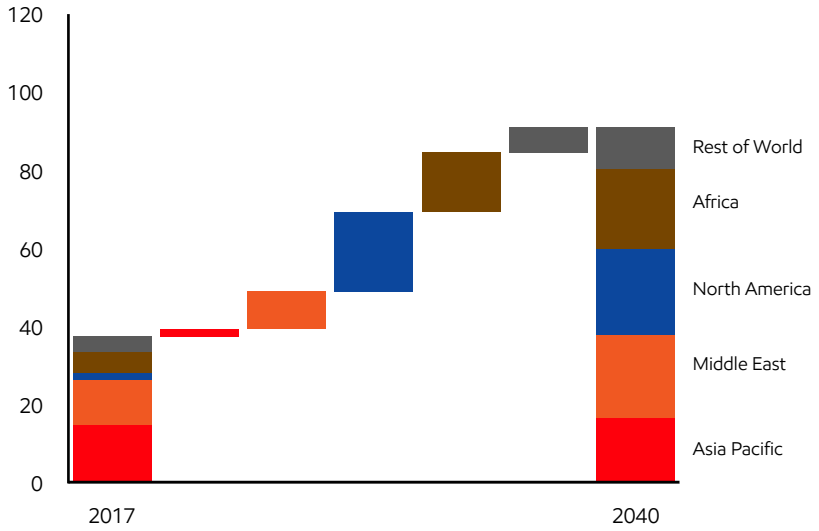
Asia Pacific and Europe benefit from LNG imports

BCFD LNG Imports



Diverse natural gas supplies underpin new LNG exports

BCFD LNG Exports



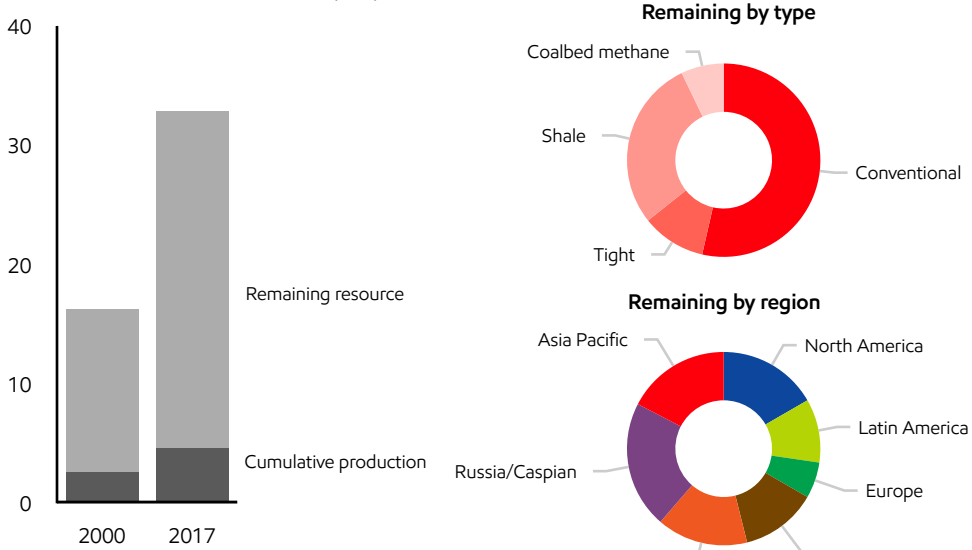
- In 2017, LNG trade met about 10 percent of global natural gas demand; by 2040, LNG trade will meet nearly 20 percent of the world's natural gas needs
- Asia Pacific absorbs about 80 percent of the growth in LNG from 2017 to 2040, helping the region to reduce its carbon intensity while sustaining economic growth and improving lives
- China's 'war on smog' and 'blue-sky' policies have led to measurable improvements in urban air quality while boosting demand for LNG imports
- India and other Asia Pacific importers are expected to look to LNG to supplement domestic natural gas production, often leveraging existing natural gas infrastructure
- Europe is expected to tap competitive LNG to diversify its natural gas import portfolio

- In 2017, 85 percent of LNG exports originated in Asia Pacific, the Middle East or Africa
- North America's LNG exports are projected to grow the most as low-cost unconventional gas production prompts investment
- East Africa, Qatar and Russia projects are expected to expand and diversify LNG exports
- The LNG market is expected to remain highly competitive due to abundant natural gas resources and many aspiring exporters
- The diversity and reliability of LNG supplies - combined with the flexibility to ship it where it is needed - make LNG a favorable choice for nations needing dependable, lower-emissions energy sources to foster economic growth

NATURAL GAS — PROJECTIONS

Technology expands recoverable resources

World – thousand trillion cubic feet (TCF)



Remaining by type

Remaining by region

Source: IEA 2001 & 2018 World Energy Outlook

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

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EMISSIONS

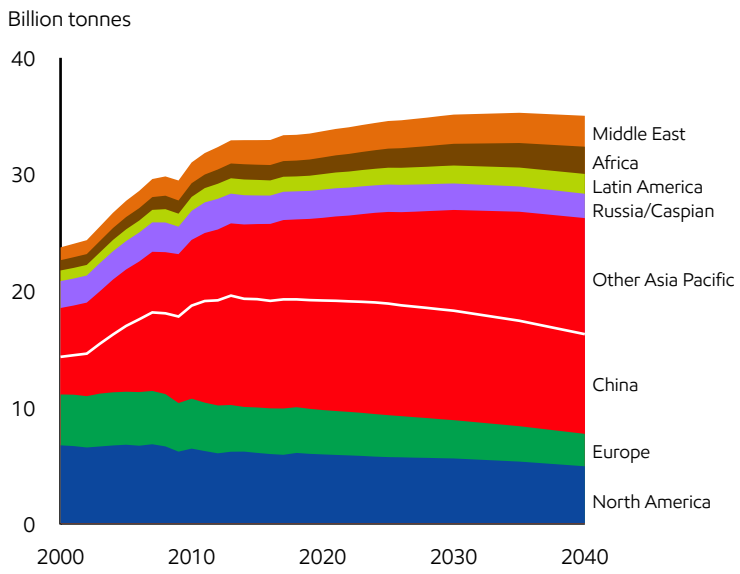
Providing reliable, affordable energy to support prosperity and enhance living standards is coupled with the need to do so in ways that reduce impacts on the environment, including the risks of climate change. This is society's dual challenge.

Billions of people need reliable, affordable energy every day, but their use of energy is contributing to CO_2 emissions. Progress on society's energy and climate objectives requires practical approaches and new technology solutions that enable human development and economic progress.

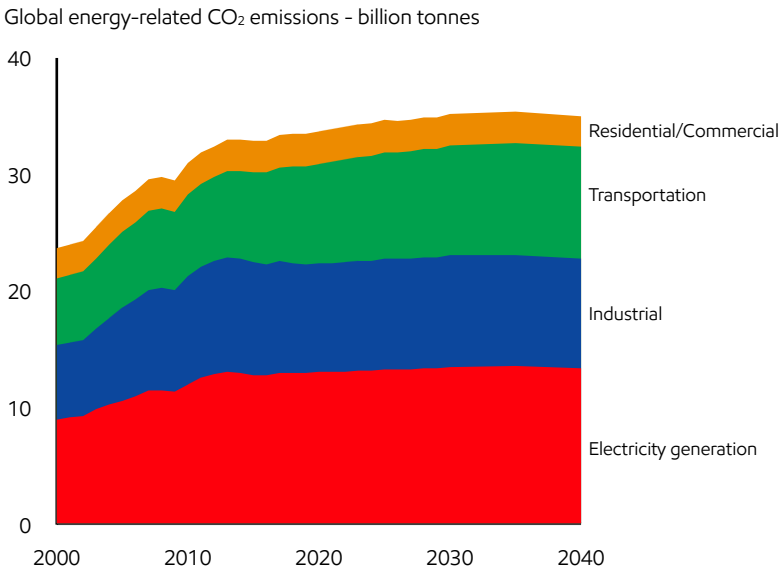
Governments bear a unique responsibility in this regard. A key challenge is to develop and implement policies that seek to address climate change risks in the most practical and cost-effective way. Policies that promote innovation can expand the available options society has for providing access to energy while reducing impacts on the environment. Additionally, policies that harness the flexibility of free markets and competition can quickly scale the best solutions for each sector within a country. Effective policy frameworks will be critical to reduce global GHG emissions and meet society's need for reliable and affordable energy.

EMISSIONS — PROJECTIONS

Energy-related CO_2 emissions peak



All sectors contributing to restrain CO_2 emissions growth

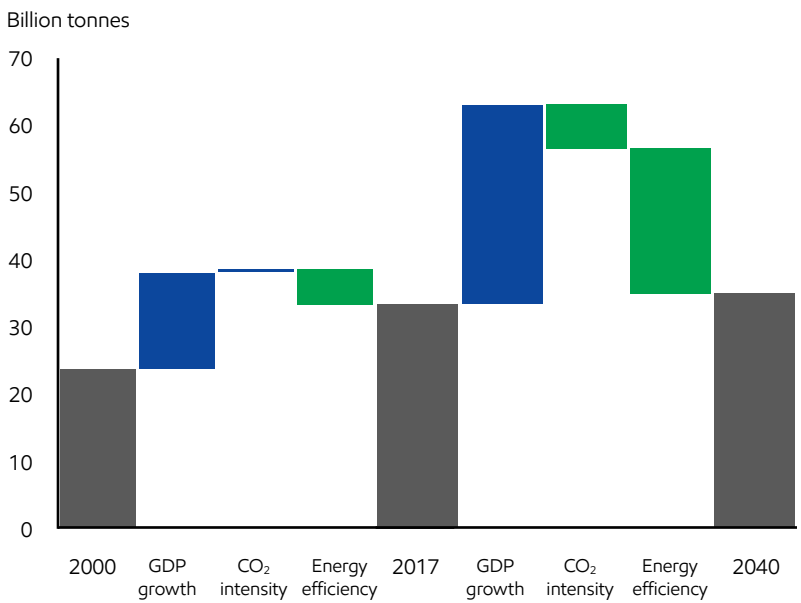


- Policy choices, consumer preferences and technology play a role in balancing energy supply and demand and the impacts on emissions.
- From 2000 to 2017 the economic expansion in Asia Pacific saw CO_2 emissions substantially rise, only partially offset by reductions in Europe and North America
- Global annual CO_2 emissions are likely to peak by 2035, at some 5 percent above 2017 levels, as various countries try to reduce the emissions intensity of their economies
- This emission projection in the chart above tracks within the estimated range of emissions implied by the NDCs for 2030 as currently submitted by the countries as part of the Paris Agreement. However, these NDCs are not on a 2°C pathway as confirmed by the United Nations Environment Programme (UNEP) 2018 report. Further discussion on decarbonization is covered in the next section, "Pursuing a 2°C pathway"

- A shift to less carbon-intensive sources of electricity (e.g., renewables, nuclear and natural gas) will reduce the CO_2 intensity of delivered electricity in 2040 by more than 35 percent compared to 2017
- Efficiency gains and growing use of less carbon-intensive energy will help reduce industrial CO_2 emissions relative to GDP by about 50 percent over the *Outlook* period
- Transportation represents about 25 percent of CO_2 emissions today, and this share is likely to grow modestly to 2040 driven by expanding commercial transportation activity
- Global light-duty vehicle CO_2 emissions are expected to peak in the early 2020s before falling by more than 15 percent from that peak by 2040, as more efficient conventional vehicles and electric cars gain significant share

EMISSIONS — PROJECTIONS

Restraining global energy-related CO_2 emissions



- The primary driver of increasing global CO_2 emissions between 2000 and 2017 was economic growth, as global GDP expanded about 60 percent
- Improving energy efficiency (energy use per unit of GDP) helped slow the growth in emissions, while global CO_2 intensity of energy use remained fairly constant, with increased coal use in some non-OECD countries offsetting improvements in the OECD countries
- As the world's economy nearly doubles by 2040, technology will be essential to mitigate emissions. Our *Outlook* projects a sustained improvement of CO_2 intensity (more solar, wind, nuclear, coal to gas switch, CCS) in addition to accelerated efficiency gains (double the historic rate from 2000 to 2017)
- By 2040 efficiency and emissions intensity reduction are expected to contribute to a nearly 45 percent decline in the carbon intensity of the global economy

Want to learn more about energy-related CO_2 emissions and ExxonMobil's views?

Download our latest Energy & Carbon Summary at:

exxonmobil.com/news/newsroom/publications-and-reports

PURSUING A 2°C PATHWAY

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 a supplement to the base *Outlook* and is intended to provide a perspective on hypothetical 2°C scenarios, highlighting the roles of new technologies, as well as oil and gas.

Since 1992, when nations around the world established the United Nations Framework Convention on Climate Change (UNFCCC), there has been an international effort to assess 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 signaled 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 change risks.[4] In this regard, the United Nations Environment Programme (UNEP) reported in November 2018 that, "Pathways reflecting current NDCs imply global warming of about 3°C by 2100, with warming continuing afterwards." Additionally, the report states, "The majority [of G20 countries] are not yet on a path that will lead them to fulfilling their NDCs for 2030." [2] In other words, the current NDCs are insufficient to meet the aim of the Paris Agreement, and moreover, not all countries are yet on track with their current policies to meet their NDCs for 2030.

THE CLIMATE CHALLENGE — CONSIDERING 2°C SCENARIOS

Exploring potential pathways to a 2°C world

According to the IEA, a "well below" 2°C pathway implies "comprehensive, systematic, immediate and ubiquitous implementation of strict energy and material efficiency measures."[5] Given a wide range of uncertainties, no single pathway can be reasonably predicted. A key unknown relates to advances in technology that may influence the cost and potential availability of certain pathways toward a 2°C scenario. Scenarios that employ a full complement of technology options are likely to provide the most economically efficient pathways.

Considerable work has been done in the scientific community to explore potential energy pathways. A comprehensive multi-model study coordinated by the Energy Modeling Forum 27 (EMF27) at Stanford University[3] brought together many energy-economic models to assess possible 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).

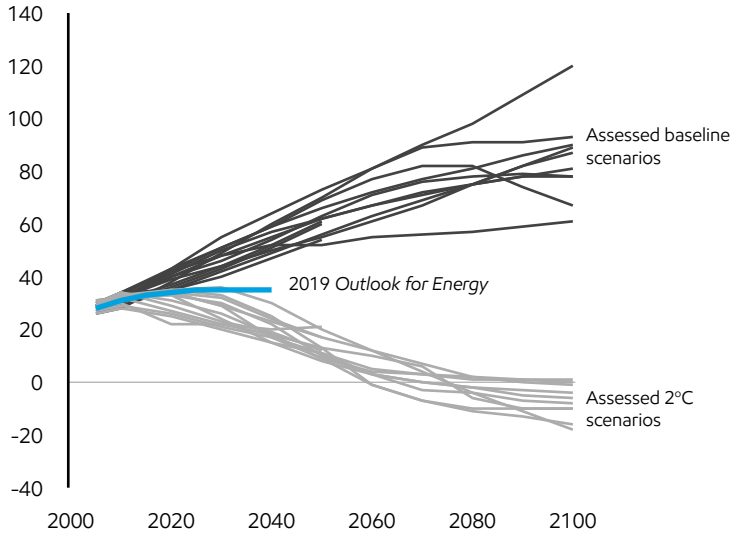
Emission and energy profiles for assessed 2°C scenarios

The chart (top right) illustrates potential global CO_2 emission trajectories under EMF27 full-technology scenarios[6] targeting a 2°C pathway (assessed 2°C scenarios) relative to the *2019 Outlook*, and relative to the EMF27 baseline pathways with essentially no policy evolution beyond those that existed in 2010.

The chart (lower right) illustrates potential global energy demand in 2040 under the assessed 2°C scenarios. The scenarios suggest that predicting absolute 2040 energy demand levels in total and by energy type carries some uncertainty, with particular scenarios likely heavily influenced by technology and policy assumptions. Differences in these scenarios help put in perspective the uncertainty in the pace and breadth of changes in the global energy landscape.

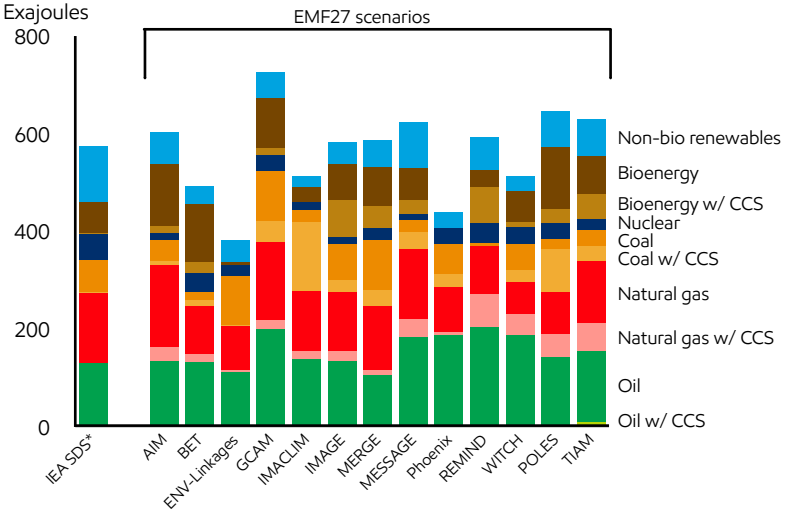
For comparison purposes, the chart (lower right) also includes energy demand projections in 2040 based on the IEA's Sustainable Development Scenario (SDS) published as part of the 2018 WEO. The IEA specifically notes that its SDS projects global energy-related CO_2 emissions that are "fully in line with the trajectory required to meet the objectives of the Paris Agreement on climate change." In fact, the SDS projects global energy-related CO_2 emissions in 2040 at a level 50 percent lower than the IEA's New Policies Scenario (NPS), which projects emissions generally in line with the aggregation of national commitments under the Paris Agreement.

Global energy-related CO_2 emissions



Assessed scenarios include CO_2 emissions from energy and industrial processes

2040 global demand by model by energy type in the assessed 2°C scenarios and the IEA SDS



*IEA WEO 2018 SDS includes CCS but breakdown by energy type is not readily identifiable

THE CLIMATE CHALLENGE – CONSIDERING 2°C SCENARIOS continued

All energy types remain important in assessed 2°C scenarios

The EMF27 full-technology scenarios also show a range of possible growth rates for each type of energy. We have taken the average of the scenarios' growth rates in order to consider potential impacts on energy demand for this report.[7]

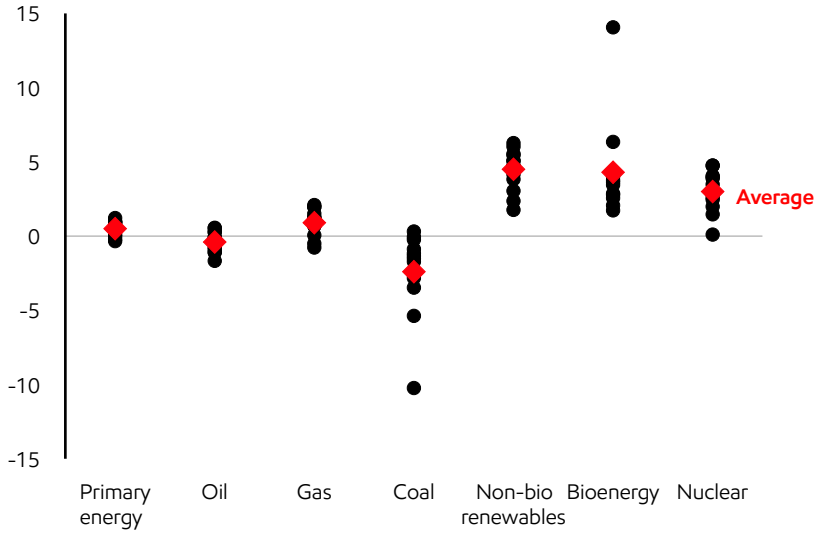
Based on this analysis, primary energy demand on a worldwide basis is projected to increase about 0.5 percent per year on average from 2010 to 2040. Expected demand and technologies deployed in 2040 vary by model and energy type (see 2°C chart on prior page and growth rates to the right):

- Oil demand is projected on average to decline by about 0.4 percent per year, while natural gas demand is expected on average to increase about 0.9 percent per year. Together their share of energy demand is projected on average to still be more than 40 percent by 2040
- The trend in demand for coal is the most negative, with an average decline of 2.4 percent per year, or about a 50 percent decline by 2040
- The projected growth for renewables and nuclear are quite strong, averaging 4.5 percent per year for non-bioenergy (e.g., hydro, wind, solar) and about 3 percent per year for nuclear
- Bioenergy demand is projected on average to grow at about 4.3 percent per year, the highest growth among all energy sources alongside non-bio renewables
- Carbon Capture and Storage (CCS) is a key technology to address CO_2 emissions, with its projected share of energy demand on average nearly double that of non-bio renewables by 2040

All energy sources remain important across all the assessed 2°C scenarios. Though the mix of energy and technology shifts over time, oil and natural gas remain important sources. Oil demand is projected to decline modestly on average, and much more slowly than its natural rate of decline from existing producing fields. Natural gas demand grows on average due to its many advantages, including lower GHG emissions as compared to coal.

EMF27-450-FT: Global demand by energy type

Average annual growth rates 2010-2040



This chart shows the average growth rate and the range of growth rates for primary energy demand and each type of energy across the scenarios.

In addition to looking at average growth rates, low-side energy growth rates for the scenarios were also considered. The low-side by energy source sees oil dropping 1.7 percent per year, natural gas dropping 0.8 percent per year, and coal dropping 10.2 percent per year through 2040. This is compared with high-side growth rates for bioenergy, nuclear and non-bio renewables of 14.1, 4.8 and 6.3 percent per year, respectively. Even under these extremes, oil and gas remain important parts of the energy mix.

THE CLIMATE CHALLENGE — POTENTIAL INVESTMENT IMPLICATIONS

Investing to meet oil and gas demand

With oil and gas a key part of the future energy mix across all of the assessed 2°C scenarios, it is important to consider the investments needed to meet society's demand.

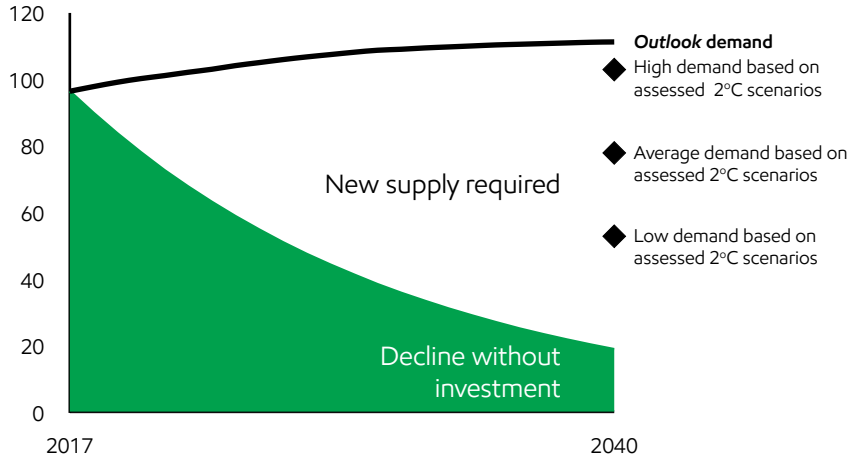
Without continued investment to sustain existing producing fields and develop new resources, the supply of oil and natural gas declines, with oil supply naturally declining at an estimated 7 percent per year, and natural gas declining at an estimated 5 percent per year. As shown in the charts on the right, these decline rates create a significant need for continuous investment just to sustain existing production levels observed in 2017.

The top chart shows that the natural rate of decline for oil far exceeds the range of demand projections in the assessed 2°C scenarios out to 2040. Similarly, the bottom chart shows that the natural rate of decline for gas also far exceeds the range of demand projections, which showed an average increase in demand over the period. Ceasing to invest in either oil or gas could lead to a significant supply shortfall versus what is needed to meet global demand, both for the near term and for the broad range of scenario demand projections.

The IEA's *2018 World Energy Outlook* estimates that significant oil and gas investment is needed to meet growing demand across a broad range of scenarios out to 2040. They estimate more than $13 trillion of investment is needed in their Sustainable Development Scenario, and almost $21 trillion would be needed in their New Policies Scenario.

Oil demand and supply warrant investment

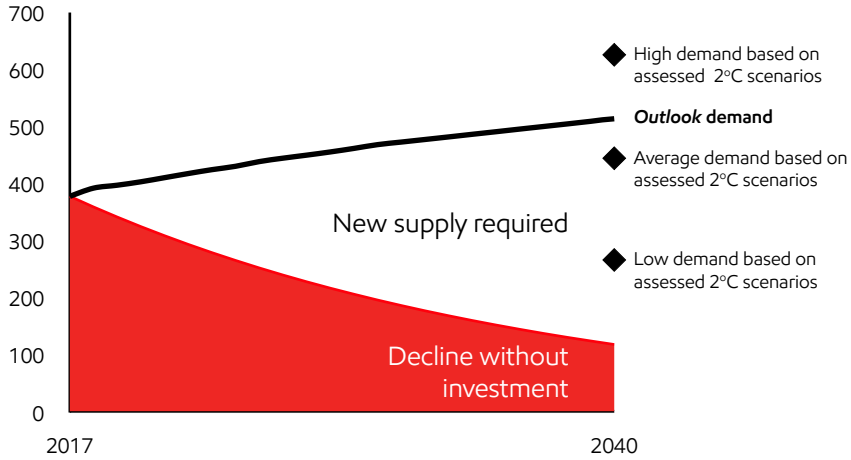
World – MBDOE



Excludes biofuels; Source: IEA, EM analyses
Assessed 2°C scenarios based on EMF27 full technology/450ppm cases targeting a 2°C pathway

Natural gas demand and supply warrant investment

World – BCFD



Source: IHS, EM analyses
Assessed 2°C scenarios based on EMF27 full technology/450ppm cases targeting a 2°C pathway

THE CLIMATE CHALLENGE — SEEKING PRACTICAL SOLUTIONS

There are no easy answers to the dual challenge of simultaneously meeting global energy demand while addressing the risks of climate change. Billions of people still lack access to modern energy; they struggle to improve their living standards and reduce the negative health impacts of energy poverty. At the same time, there is growing recognition among parties that emission reductions are not yet sufficient to achieve a 2°C pathway.[2]

Effectively addressing this dual challenge will require practical, cost-effective solutions. Cost is an important consideration as it is estimated that currently nearly 2 billion people (~30 percent of the population), live on less than $1,200 per year[8]. Even a minor increase in cost of living is problematic for this vulnerable population. Awareness of this enduring economic, energy and environmental disparity across the globe is a reminder of the need to develop practical and economic solutions for addressing the risks of climate change.

Opportunities exist worldwide across all sectors to reduce energy-related emissions. The chart on the lower right shows 2017 energy-related CO_2 emissions across the sectors and highlights where new solutions can have the largest impact in reducing emissions.

Addressing the dual challenge across all of these sectors requires progress in four key areas:

1. Boosting energy efficiency
2. Shifting the energy mix to lower-carbon sources
3. Adopting policies to promote cost-effective solutions
4. Investing in research and development to advance technology

Boosting energy efficiency

Capturing the most cost-effective efficiency gains will become even more important to spare society an unnecessary economic burden associated with high-cost options to reduce emissions. Boosting efficiency will require effective investments and sound policies to promote them. These investments often create a win-win situation because the lower energy consumption reduces both emissions and consumers' energy bills.

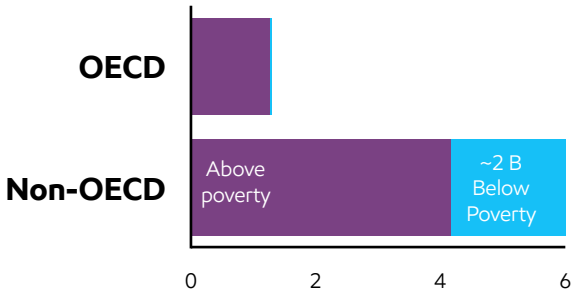
Opportunities to boost efficiency are many and varied, ranging from better equipment (e.g., light bulbs, vehicles, appliances) to improved building designs, to better manufacturing techniques in industrial applications. Importantly, not all of the same mechanisms apply across all energy sectors.

Shifting the energy mix to lower-carbon sources

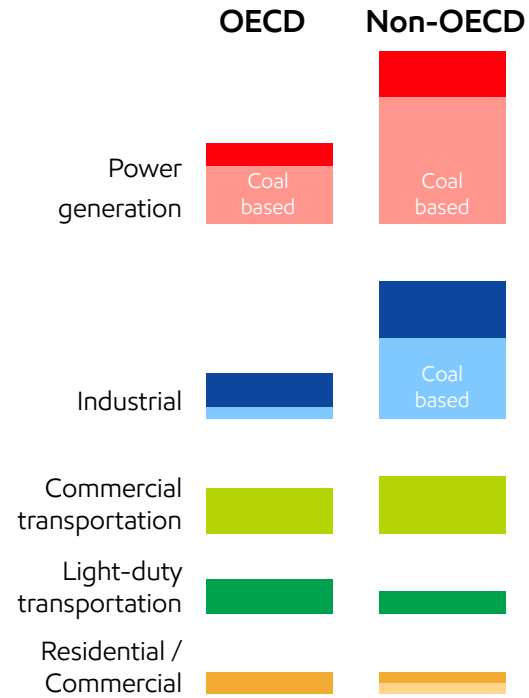
Shifting the CO_2 emissions intensity of the energy mix to lower levels while keeping energy reliable and affordable also requires investment. Power generation has the most commercially developed lower-carbon alternatives: natural gas, bioenergy, renewables, nuclear, CCS. Options at commercial scale are currently more limited for the industrial and commercial transportation sectors, which represented nearly half of energy-related CO_2 emissions in 2017, and have projected strong demand growth out to 2040, making these sectors challenging to decarbonize. New technology solutions (such as advanced biofuels, hydrogen and novel batteries) will be required.

2017 global population and poverty

Billions of people (poverty line at $3.20 per day per person)



2017 energy-related CO_2 emissions by sector



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 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 costs and benefits of options and rely on market-based solutions are needed.

An economy-wide price on carbon, whether based on a tax, trading mechanisms or other market-based measures, can lead to cost-effective emissions reduction. 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." [9]

Investing in research and development to advance technology

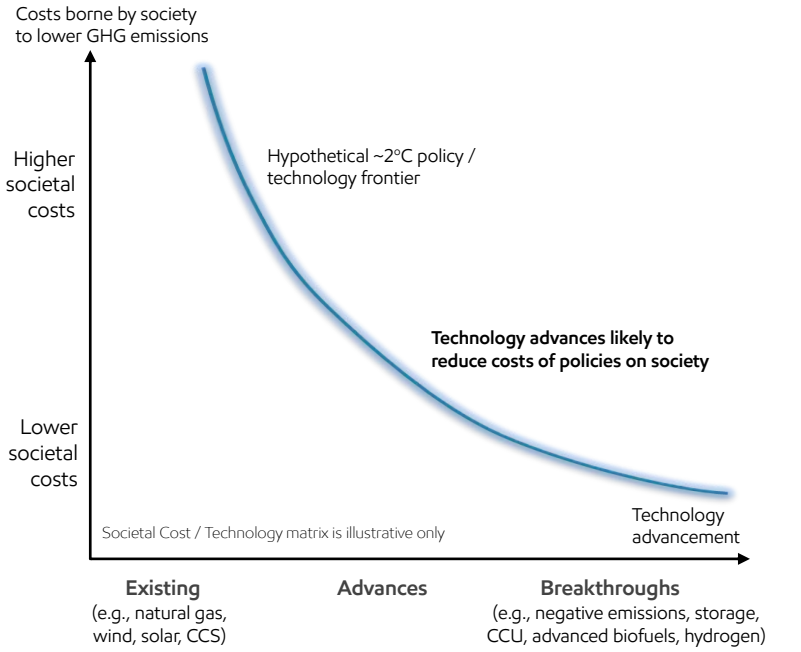
Technology advances will also be important to help minimize the costs of reducing emissions while also delivering increased access to reliable and affordable energy. However, the International Energy Agency in 2019 estimated in its Tracking Clean Energy Progress analysis that only 7 of 45 technologies are on track to help society reach the Paris Agreement climate goals[10] . Electric light-duty Vehicles, one technology highlighted by the IEA, are on track to meet the IEA's Sustainable Development target, but light-duty transportation is just one sector and represented less than 10 percent of global energy demand and emissions in 2017. Advancing technology for cost-effective solutions will be critical to pursue a 2°C pathway while helping keep energy reliable and affordable for a growing population.

As the graphic to the right shows, expanding technology options through research and development can play a role in reducing the costs borne by society to lower emissions while still meeting energy needs. Existing technologies, like wind, solar and natural gas with CCS, play important roles in hypothetical 2°C pathways, but advances are needed to further reduce their costs so that increased use does not raise electricity costs for consumers.

Further breakthroughs are needed to develop and deploy new solutions at commercial scale across all sectors. The table to the right highlights some areas where these breakthroughs are needed. For example, improving the design and function of power grids or achieving cost-effective long-duration storage (i.e., seasonal storage) could allow higher penetration of variable renewables like wind and solar.

For commercial transportation, advanced biofuels that do not compete with the food chain could provide a new lower carbon solution, but technology breakthroughs are needed to lower land-use and costs to produce.

Technology key to reducing societal costs of 2°C pathway



Technology breakthrough opportunities
Power grid reliability & long-duration storage: Batteries, chemical storage, hydrogen
Lower-carbon commercial transport: algae & cellulosic biofuels, fuel cells, batteries
Lower-carbon industrial processes: carbon capture, hydrogen, process intensification
Advanced, less carbon-intensive materials for efficient buildings and infrastructure
Negative emissions: bioenergy with carbon capture, direct air capture, CO_2 utilization

THE CLIMATE CHALLENGE – SEEKING PRACTICAL SOLUTIONS continued

Technologies that could achieve "negative emissions," such as direct air capture or bioenergy with carbon capture, were found to be an important part of the assessed 2°C scenarios. Many of these scenarios employed negative emissions where possible to offset harder and more costly to decarbonize sectors like industrial and transportation.

Without expanding the existing technology options, the stringency of policies and their related costs to society could increase. If society pushes back on some of these policies, it could risk setbacks on climate progress. Technology advances combined with sound policies improve society's chances of achieving the goals of the Paris Agreement.

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 the potential implications. The world cannot afford to prematurely foreclose options or negate reliable, affordable and practical energy systems upon which billions of people depend.

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.

Want to learn more about how ExxonMobil is working to advance technology and provide new solutions to address the dual challenge?

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ENERGY MATTERS

With the world's population estimated to reach more than 9 billion people in 2040, providing enough affordable energy to help improve global living standards is a significant challenge. We expect that continued progress, powered by human ingenuity and technology, will help make better lives possible, while appropriately addressing the risks of climate change.

Meeting energy demand safely, reliably and affordably – while also minimizing risks and potential 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.

9.2B
Global population is projected to grow to 9.2 billion from today's 7.5 billion

2X
The world's economy is expected to grow faster than population, almost doubling by 2040

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
									2017	2017		
Regions	2000	2010	2017	2020	2025	2030	2035	2040	2040	2040	2017	2040
World	405	513	562	581	609	636	658	675	0.8%	20%	100%	100%
OECD	219	224	220	222	218	216	213	208	(0.2)%	(6)%	39%	31%
Non-OECD	186	289	342	359	391	420	445	467	1.4%	37%	61%	69%
Africa	22	29	35	37	42	47	52	58	2.2%	67%	6%	9%
Asia Pacific	122	199	237	249	271	288	304	316	1.2%	33%	42%	47%
China	46	99	123	128	137	142	147	148	0.8%	21%	22%	22%
India	18	27	35	39	46	53	60	66	2.8%	90%	6%	10%
Europe	77	80	78	77	75	73	71	69	(0.5)%	(11)%	14%	10%
European Union	71	72	68	67	64	62	60	57	(0.7)%	(16)%	12%	9%
Latin America	19	25	28	28	31	33	36	38	1.4%	37%	5%	6%
Middle East	17	28	36	37	40	43	45	48	1.2%	32%	6%	7%
North America	111	109	108	110	110	111	110	108	—%	—%	19%	16%
United States	94	91	88	91	90	90	89	87	(0.1)%	(2)%	16%	13%
Russia/Caspian	37	42	42	42	42	41	40	40	(0.2)%	(5)%	7%	6%
Energy by type - World												
Primary	405	513	562	581	609	636	658	675	0.8%	20%	100%	100%
Oil	147	164	180	187	195	201	204	205	0.6%	14%	32%	30%
Natural gas	89	116	130	139	151	162	169	177	1.3%	36%	23%	26%
Coal	91	140	147	142	140	138	137	133	(0.4)%	(9)%	26%	20%
Nuclear	27	29	27	31	32	36	41	45	2.2%	66%	5%	7%
Biomass/Waste	40	46	51	52	53	55	55	56	0.4%	9%	9%	8%
Hydro	9	12	14	15	16	17	18	18	1.2%	30%	2%	3%
Other Renewables	3	7	13	17	23	28	34	41	5.1%	213%	2%	6%
End-use sectors - World												
Residential and commercial												
Total	96	110	116	120	127	131	136	139	0.8%	20%	100%	100%
Oil	14	12	12	12	11	11	10	10	(0.7)%	(15)%	10%	7%
Natural gas	21	24	26	27	28	28	29	29	0.5%	13%	22%	21%
Biomass/Waste	29	30	30	30	31	31	30	30	—%	(1)%	26%	21%
Electricity	23	32	37	41	46	51	56	60	2.1%	63%	32%	43%
Other	10	11	12	11	11	11	10	10	(0.6)%	(12)%	10%	7%
Transportation												
Total	77	95	110	118	126	132	137	140	1.0%	27%	100%	100%
Oil	75	91	104	110	116	120	121	121	0.7%	16%	94%	86%
Biofuels	0	2	3	4	4	5	5	6	2.5%	77%	3%	4%
Natural gas	0	1	2	3	3	4	5	6	5.7%	261%	2%	5%
Other	1	1	1	1	2	3	5	7	8.0%	493%	1%	5%
Industrial												
Total	143	194	213	216	226	236	243	250	0.7%	17%	100%	100%
Oil	44	50	55	56	59	63	65	67	0.9%	23%	26%	27%
Natural gas	37	45	51	54	57	61	63	66	1.2%	30%	24%	26%
Coal	26	51	51	47	47	46	45	43	(0.7)%	(15)%	24%	17%
Electricity	22	31	37	40	43	46	50	53	1.6%	43%	18%	21%
Other	14	18	20	20	20	20	20	20	0.1%	2%	9%	8%
Power generation - World												
Primary	146	190	211	220	233	248	263	277	1.2%	31%	100%	100%
Oil	14	11	10	9	8	8	7	6	(1.8)%	(34)%	5%	2%
Natural gas	31	46	52	56	63	68	72	76	1.6%	46%	25%	28%
Coal	61	84	91	91	90	89	89	88	(0.2)%	(4)%	43%	32%
Nuclear	27	29	27	31	32	36	41	45	2.2%	66%	13%	16%
Hydro	9	12	14	15	16	17	18	18	1.2%	30%	7%	7%
Wind	0	1	4	5	8	11	14	17	6.6%	339%	2%	6%
Other Renewables	4	7	13	14	17	20	23	26	3.3%	109%	6%	10%
Electricity demand (terawatt hours)												
World	13195	18602	22168	23995	26615	29463	32320	35277	2.0%	59%	100%	100%
OECD	8581	9721	9853	10115	10442	10923	11329	11766	0.8%	19%	44%	33%
Non-OECD	4614	8881	12315	13880	16173	18540	20991	23511	2.9%	91%	56%	67%

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
OECD									2017	2017		
Energy by type	**2000**	**2010**	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2017**	**2040**
Primary	219	224	220	222	218	216	213	208	(0.2)%	(6)%	100%	100%
Oil	92	86	85	86	84	81	78	75	(0.6)%	(12)%	39%	36%
Natural gas	47	55	58	62	64	66	66	67	0.6%	15%	26%	32%
Coal	43	42	34	29	24	20	17	13	(4.0)%	(61)%	16%	6%
Nuclear	23	24	20	21	20	19	19	19	(0.2)%	(4)%	9%	9%
Biomass/waste	7	9	10	10	11	11	11	11	0.3%	8%	5%	5%
Hydro	5	5	5	5	5	5	5	5	0.5%	12%	2%	3%
Other renewables	2	4	7	9	11	13	15	17	3.9%	141%	3%	8%
End-use sectors												
Residential and commercial												
Total	46	50	47	48	48	47	46	45	(0.2)%	(4)%	100%	100%
Oil	9	7	5	5	4	3	3	2	(3.9)%	(60)%	11%	5%
Natural gas	16	17	16	17	16	16	15	15	(0.4)%	(9)%	34%	33%
Biomass/waste	2	3	3	3	3	2	2	2	(1.3)%	(26)%	6%	4%
Electricity	17	21	21	22	23	23	24	24	0.7%	17%	44%	54%
Other	2	3	2	2	2	2	2	2	(0.8)%	(17)%	5%	4%
Transportation												
Total	52	54	56	58	58	57	56	55	(0.1)%	(3)%	100%	100%
Oil	51	52	54	55	54	53	51	48	(0.5)%	(11)%	95%	88%
Biofuels	0	2	2	2	2	3	3	3	1.4%	37%	4%	5%
Natural gas	0	0	0	0	1	1	1	1	9.7%	736%	–%	3%
Other	0	0	0	0	1	1	2	2	8.1%	501%	1%	4%
Industrial												
Total	68	65	67	67	68	68	68	68	–%	1%	100%	100%
Oil	25	24	24	24	25	25	24	24	–%	–%	36%	36%
Natural gas	18	18	20	21	22	23	23	23	0.6%	15%	29%	33%
Coal	8	7	6	5	4	4	3	3	(3.5)%	(56)%	9%	4%
Electricity	12	12	12	12	12	13	13	14	0.4%	9%	18%	20%
Other	4	4	4	4	4	5	5	5	0.1%	2%	7%	7%
Power generation												
Primary	86	90	85	85	83	83	83	82	(0.2)%	(4)%	100%	100%
Oil	7	3	2	2	1	1	1	1	(5.8)%	(74)%	3%	1%
Natural gas	14	20	22	23	25	27	27	28	1.0%	26%	26%	34%
Coal	35	34	27	23	19	16	13	10	(4.1)%	(62)%	32%	13%
Nuclear	23	24	20	21	20	19	19	19	(0.2)%	(4)%	23%	23%
Hydro	5	5	5	5	5	5	5	5	0.5%	12%	6%	6%
Wind	0	1	2	3	4	6	7	8	5.4%	235%	3%	10%
Other renewables	3	4	7	8	9	10	10	11	2.2%	65%	8%	14%

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									2017	2017		
Energy by type	**2000**	**2010**	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2017**	**2040**
Primary	186	289	342	359	391	420	445	467	1.4%	37%	100%	100%
Oil	55	78	95	101	111	119	125	130	1.4%	37%	28%	28%
Natural gas	41	61	72	78	87	96	103	110	1.9%	53%	21%	24%
Coal	48	98	112	112	116	118	120	120	0.3%	6%	33%	26%
Nuclear	4	5	7	9	12	17	22	26	5.8%	268%	2%	6%
Biomass/waste	33	37	41	41	43	44	44	44	0.4%	9%	12%	9%
Hydro	4	7	9	10	11	12	12	13	1.5%	40%	3%	3%
Other renewables	1	3	6	8	12	15	19	24	6.2%	298%	2%	5%
End-use sectors												
Residential and commercial												
Total	50	60	68	72	79	84	89	94	1.4%	37%	100%	100%
Oil	5	5	6	7	7	7	8	8	0.8%	21%	9%	8%
Natural gas	5	7	9	10	12	13	13	14	1.8%	50%	14%	15%
Biomass/waste	26	27	27	27	28	28	28	28	0.1%	2%	40%	30%
Electricity	6	11	16	19	23	27	32	36	3.5%	122%	24%	39%
Other	8	8	9	9	9	9	8	8	(0.5)%	(11)%	13%	9%
Transportation												
Total	25	41	54	60	68	75	81	86	2.0%	59%	100%	100%
Oil	24	38	51	55	62	67	70	73	1.6%	45%	93%	86%
Biofuels	0	1	1	1	2	2	3	3	4.1%	150%	2%	3%
Natural gas	0	1	2	2	3	3	4	5	5.0%	208%	3%	6%
Other	0	1	1	1	1	2	3	5	8.0%	489%	1%	5%
Industrial												
Total	76	129	146	149	159	168	175	182	1.0%	25%	100%	100%
Oil	19	26	30	32	35	38	41	43	1.5%	42%	21%	24%
Natural gas	19	27	31	32	35	38	41	43	1.5%	40%	21%	24%
Coal	18	44	45	42	42	42	41	41	(0.4)%	(10)%	31%	22%
Electricity	9	19	25	28	31	34	37	40	2.1%	60%	17%	22%
Other	10	13	15	15	16	16	16	16	0.1%	3%	10%	9%
Power generation												
Primary	60	100	126	135	150	165	181	194	1.9%	55%	100%	100%
Oil	7	8	8	7	7	7	6	6	(1.1)%	(23)%	6%	3%
Natural gas	17	26	30	33	38	42	45	49	2.1%	60%	24%	25%
Coal	26	51	64	68	71	73	76	77	0.8%	20%	51%	40%
Nuclear	4	5	7	9	12	17	22	26	5.8%	268%	6%	13%
Hydro	4	7	9	10	11	12	12	13	1.5%	40%	7%	7%
Wind	0	0	1	2	4	5	7	9	8.1%	503%	1%	5%
Other renewables	1	3	6	7	9	10	13	15	4.2%	160%	5%	8%

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change	% change	Share of total	
									2017	2017		
Regions	2000	2010	2017	2020	2025	2030	2035	2040	2040	2040	2017	2040
AFRICA												
Primary	22	29	35	37	42	47	52	58	2.2%	67%	100%	100%
Oil	5	7	8	9	10	12	14	16	2.8%	88%	24%	27%
Natural gas	4	5	6	7	9	10	12	14	3.7%	133%	17%	24%
Coal	3	4	4	4	4	4	4	4	0.2%	5%	11%	7%
Nuclear	0	0	0	0	0	0	1	1	7.3%	401%	–%	1%
Biomass/waste	10	13	16	16	18	19	20	21	1.2%	32%	45%	36%
Hydro	0	0	0	1	1	1	1	1	4.9%	199%	1%	2%
Other renewables	0	0	0	0	1	1	1	2	9.0%	633%	1%	3%
Demand by sector												
Total end-use (including electricity)	19	26	30	32	36	40	44	48	2.0%	59%	100%	100%
Residential and commercial	9	12	14	15	17	19	21	23	2.1%	61%	47%	48%
Transportation	3	4	5	6	7	8	9	10	2.5%	76%	18%	20%
Industrial	7	9	10	11	12	13	14	16	1.7%	49%	35%	32%
Memo: electricity demand	1	2	2	3	4	4	6	7	4.9%	203%	8%	14%
Power generation fuel[1]	4	6	7	8	9	12	14	17	4.0%	145%	19%	29%
ASIA PACIFIC												
Primary	122	199	237	249	271	288	304	316	1.2%	33%	100%	100%
Oil	40	52	63	67	73	77	79	80	1.0%	27%	27%	25%
Natural gas	11	21	29	33	39	44	48	52	2.6%	81%	12%	16%
Coal	43	94	109	107	110	112	114	114	0.2%	5%	46%	36%
Nuclear	5	6	5	8	11	15	19	22	6.5%	330%	2%	7%
Biomass/Waste	20	20	21	20	20	20	20	19	(0.3)%	(8)%	9%	6%
Hydro	2	4	6	6	7	7	7	8	1.3%	34%	2%	2%
Other Renewables	1	2	5	7	10	13	17	21	6.1%	294%	2%	7%
Demand by sector												
Total end-use (including electricity)	95	152	180	188	204	216	226	234	1.1%	30%	100%	100%
Residential and commercial	31	36	42	44	48	51	54	56	1.3%	34%	23%	24%
Transportation	17	26	35	40	45	49	53	55	2.0%	56%	20%	24%
Industrial	47	89	103	104	111	116	120	123	0.8%	19%	57%	53%
Memo: electricity demand	12	24	34	39	45	50	56	62	2.6%	81%	19%	27%
Power generation fuel[1]	40	74	96	104	116	127	139	149	1.9%	55%	40%	47%
EUROPE												
Primary	77	80	78	77	75	73	71	69	(0.5)%	(11)%	100%	100%
Oil	31	29	28	28	27	26	24	22	(1.0)%	(20)%	36%	33%
Natural gas	17	20	19	18	19	19	18	18	(0.1)%	(3)%	24%	26%
Coal	14	13	11	10	8	6	5	4	(4.5)%	(65)%	14%	6%
Nuclear	10	10	9	9	7	8	8	8	(0.6)%	(12)%	11%	11%
Biomass/Waste	3	5	6	6	7	7	7	7	0.8%	20%	8%	11%
Hydro	2	2	2	2	2	2	2	2	0.5%	13%	3%	3%
Other Renewables	0	2	3	4	5	6	6	7	3.6%	125%	4%	10%
Demand by sector												
Total end-use (including electricity)	59	62	61	61	60	59	57	55	(0.4)%	(9)%	100%	100%
Residential and commercial	18	21	20	19	19	18	18	17	(0.7)%	(14)%	32%	31%
Transportation	17	18	19	19	19	19	19	18	(0.2)%	(5)%	31%	33%
Industrial	25	23	22	22	22	21	21	20	(0.4)%	(9)%	37%	37%
Memo: electricity demand	10	12	12	12	12	13	13	14	0.8%	20%	19%	25%
Power generation fuel[1]	30	32	30	30	29	29	29	29	(0.2)%	(5)%	39%	42%

[1]Share based on total primary energy

Energy demand (quadrillion BTUs, unless otherwise noted)									Average annual change 2017	% change 2017	Share of total	
Regions	**2000**	**2010**	**2017**	**2020**	**2025**	**2030**	**2035**	**2040**	**2040**	**2040**	**2017**	**2040**
LATIN AMERICA												
Primary	19	25	28	28	31	33	36	38	1.4%	37%	100%	100%
Oil	9	11	12	12	13	14	15	15	1.2%	31%	43%	41%
Natural gas	4	6	6	6	7	8	9	10	2.2%	65%	22%	27%
Coal	1	1	1	1	1	1	1	1	(1.2)%	(24)%	4%	2%
Nuclear	0	0	0	0	0	1	1	1	3.7%	132%	1%	1%
Biomass/waste	3	4	5	5	5	5	5	5	–%	–%	17%	12%
Hydro	2	2	2	3	3	3	3	3	1.5%	41%	9%	9%
Other renewables	0	1	1	1	2	2	2	3	3.9%	142%	4%	7%
Demand by sector												
Total end-use (including electricity)	17	22	23	25	26	29	31	33	1.5%	40%	100%	100%
Residential and commercial	3	4	4	5	5	5	6	6	1.3%	35%	19%	18%
Transportation	5	7	8	8	9	10	11	11	1.7%	46%	33%	35%
Industrial	9	12	11	12	12	13	14	15	1.4%	37%	48%	47%
Memo: electricity demand	2	3	4	4	5	5	6	6	2.4%	72%	16%	19%
Power generation fuel[1]	4	6	8	8	9	10	11	11	1.7%	46%	28%	30%
MIDDLE EAST												
Primary	17	28	36	37	40	43	45	48	1.2%	32%	100%	100%
Oil	10	14	17	17	17	19	19	19	0.6%	15%	46%	40%
Natural gas	7	13	19	19	21	23	25	26	1.5%	41%	52%	55%
Coal	0	0	0	0	0	0	0	0	(5.5)%	(73)%	1%	–%
Nuclear	0	0	0	0	0	1	1	1	11.8%	1189%	–%	2%
Biomass/Waste	0	0	0	0	0	0	0	0	7.4%	416%	–%	–%
Hydro	0	0	0	0	0	0	0	0	1.3%	35%	–%	–%
Other Renewables	0	0	0	0	0	0	1	1	12.6%	1445%	–%	2%
Demand by sector												
Total end-use (including electricity)	13	22	28	28	31	33	36	37	1.3%	36%	100%	100%
Residential and commercial	3	4	5	5	6	7	7	7	1.6%	43%	19%	20%
Transportation	4	6	8	8	9	10	10	11	1.3%	34%	29%	28%
Industrial	7	11	14	14	16	17	18	19	1.3%	34%	52%	52%
Memo: electricity demand	1	3	3	4	4	5	6	6	2.8%	88%	12%	17%
Power generation fuel[1]	5	9	12	12	13	15	16	16	1.5%	40%	33%	35%
NORTH AMERICA												
Primary	111	109	108	110	110	111	110	108	–%	–%	100%	100%
Oil	45	43	43	44	44	44	43	42	(0.1)%	(3)%	40%	38%
Natural gas	26	28	32	35	37	39	39	40	1.0%	25%	29%	37%
Coal	23	21	14	13	10	8	6	4	(5.1)%	(70)%	13%	4%
Nuclear	9	10	10	9	9	8	8	8	(0.6)%	(13)%	9%	8%
Biomass/Waste	4	3	3	3	3	3	3	3	(0.3)%	(6)%	3%	3%
Hydro	2	2	2	2	2	3	3	3	0.4%	10%	2%	3%
Other Renewables	1	2	3	4	5	6	7	8	3.9%	143%	3%	8%
Demand by sector												
Total end-use (including electricity)	82	82	84	87	88	90	90	89	0.3%	6%	100%	100%
Residential and commercial	22	23	22	23	23	23	23	22	0.1%	3%	26%	25%
Transportation	28	30	30	32	32	32	31	30	–%	–%	36%	34%
Industrial	32	30	32	32	34	35	36	36	0.6%	14%	38%	41%
Memo: electricity demand	14	16	16	16	17	18	19	19	0.8%	21%	19%	22%
Power generation fuel[1]	44	43	40	40	39	39	39	39	(0.2)%	(4)%	37%	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	2017	2020	2025	2030	2035	2040	2017 2040	2017 2040	2017	2040
RUSSIA/CASPIAN												
Primary	37	42	42	42	42	41	40	40	(0.2)%	(5)%	100%	100%
Oil	7	8	9	10	10	10	10	10	0.4%	8%	22%	26%
Natural gas	20	23	21	21	20	19	18	18	(0.7)%	(15)%	50%	45%
Coal	7	7	7	7	7	6	6	5	(1.1)%	(22)%	17%	14%
Nuclear	2	3	3	3	4	4	4	4	1.9%	53%	7%	11%
Biomass/waste	0	0	1	1	1	1	1	1	0.9%	22%	1%	2%
Hydro	1	1	1	1	1	1	1	1	—%	1%	2%	2%
Other renewables	0	0	0	0	0	0	0	0	10.2%	824%	—%	1%
Demand by sector												
Total end-use (including electricity)	29	33	33	34	34	34	33	33	(0.1)%	(2)%	100%	100%
Residential and commercial	9	9	9	9	9	8	8	8	(0.7)%	(14)%	26%	23%
Transportation	3	4	5	5	5	5	5	5	0.3%	7%	14%	15%
Industrial	17	20	20	20	20	20	20	20	—%	1%	60%	62%
Memo: electricity demand	3	4	4	5	5	5	5	5	0.9%	22%	13%	16%
Power generation fuel[1]	19	20	18	18	18	17	17	16	(0.5)%	(11)%	44%	41%
GDP by region (2010$, trillions)												
World	50	66	80	88	101	116	133	151	2.8%	89%	100%	100%
OECD	38	45	51	54	60	65	71	78	1.8%	52%	64%	51%
Non-OECD	12	21	29	33	42	51	62	74	4.1%	153%	36%	49%
Africa	1	2	3	3	3	4	5	6	4.0%	144%	3%	4%
Asia Pacific	12	19	26	30	37	44	53	62	3.8%	138%	33%	41%
China	2	6	10	12	16	20	24	29	4.7%	189%	13%	19%
India	1	2	3	3	5	6	8	10	6.0%	279%	3%	7%
Europe	16	19	21	23	25	27	29	31	1.7%	47%	27%	21%
European Union	15	17	19	20	22	23	25	27	1.6%	43%	23%	18%
Latin America	3	4	5	5	6	6	7	9	2.8%	87%	6%	6%
Middle East	1	2	3	3	3	4	5	5	3.1%	103%	3%	4%
North America	15	18	20	22	24	27	30	34	2.2%	64%	26%	22%
United States	13	15	17	19	21	23	25	28	2.2%	63%	22%	19%
Russia/Caspian	1	2	2	3	3	3	4	4	2.2%	65%	3%	3%
Energy intensity (thousand BTU per $ GDP)												
World	8.1	7.8	7.0	6.6	6.0	5.5	4.9	4.5	(2.0)%	(36)%		
OECD	5.7	5.0	4.3	4.1	3.7	3.3	3.0	2.7	(2.1)%	(38)%		
Non-OECD	15.9	13.5	11.7	10.8	9.4	8.2	7.2	6.3	(2.6)%	(46)%		
Africa	18.6	14.8	13.9	13.2	12.1	11.1	10.3	9.5	(1.6)%	(32)%		
Asia Pacific	10.1	10.4	9.0	8.3	7.4	6.5	5.7	5.1	(2.5)%	(44)%		
China	20.4	16.3	12.1	10.5	8.7	7.2	6.0	5.1	(3.7)%	(58)%		
India	21.2	16.1	12.8	11.5	9.9	8.6	7.4	6.4	(3.0)%	(50)%		
Europe	4.7	4.2	3.6	3.4	3.0	2.7	2.4	2.2	(2.2)%	(40)%		
European Union	4.8	4.3	3.6	3.4	3.0	2.7	2.4	2.1	(2.3)%	(41)%		
Latin America	6.4	6.0	6.0	5.9	5.5	5.2	4.8	4.4	(1.3)%	(27)%		
Middle East	12.3	13.1	13.6	12.7	11.7	10.8	9.8	8.9	(1.8)%	(35)%		
North America	7.5	6.2	5.3	5.0	4.5	4.1	3.6	3.2	(2.1)%	(39)%		
United States	7.5	6.1	5.1	4.9	4.3	3.9	3.5	3.1	(2.2)%	(40)%		
Russia/Caspian	29.5	19.7	17.3	16.4	14.5	12.8	11.3	10.0	(2.4)%	(42)%		
Energy-related CO_2 emissions (billion tonnes)												
World	23.8	31.0	33.4	33.7	34.6	35.1	35.3	35.0	0.2%	5%	100%	100%
OECD	13.0	12.8	12.1	11.8	11.2	10.7	10.1	9.4	(1.1)%	(23)%	36%	27%
Non-OECD	10.8	18.2	21.3	21.9	23.4	24.4	25.2	25.7	0.8%	21%	64%	73%
Africa	0.9	1.2	1.3	1.4	1.6	1.9	2.1	2.3	2.4%	74%	4%	7%
Asia Pacific	7.4	13.6	16.2	16.5	17.4	18.0	18.4	18.5	0.6%	14%	48%	53%
China	3.2	8.0	9.4	9.4	9.6	9.4	9.0	8.5	(0.4)%	(9)%	28%	24%
India	0.9	1.6	2.2	2.5	2.9	3.4	3.9	4.3	3.0%	97%	7%	12%
Europe	4.4	4.3	4.0	3.8	3.6	3.3	3.0	2.8	(1.5)%	(30)%	12%	8%
European Union	4.0	3.8	3.4	3.3	3.0	2.7	2.5	2.2	(1.9)%	(35)%	10%	6%
Latin America	0.9	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.2%	32%	4%	5%
Middle East	1.1	1.8	2.2	2.2	2.4	2.5	2.6	2.7	0.8%	19%	7%	8%
North America	6.8	6.5	6.0	6.0	5.8	5.7	5.4	5.0	(0.8)%	(16)%	18%	14%
United States	5.9	5.5	5.0	5.0	4.8	4.7	4.4	4.0	(0.9)%	(20)%	15%	11%
Russia/Caspian	2.3	2.5	2.4	2.4	2.3	2.3	2.2	2.1	(0.7)%	(14)%	7%	6%

[1]Share based on total primary energy

HOW WE DEVELOP OUR *OUTLOOK*

ExxonMobil uses a data-driven approach to understand potential future energy demand and supply.

MONITORING POLICY AND TECHNOLOGY TRENDS
Throughout the process, we monitor changes in technology, such as cost decreases for solar panels, improvements in battery technology and advances in well completion technology for tight oil. We also follow policy developments, such as adopted policies and ambitions formulated in context of the Paris Agreement, the European Union's recently adopted tailpipe emissions regulations and China's 'blue sky' policies.

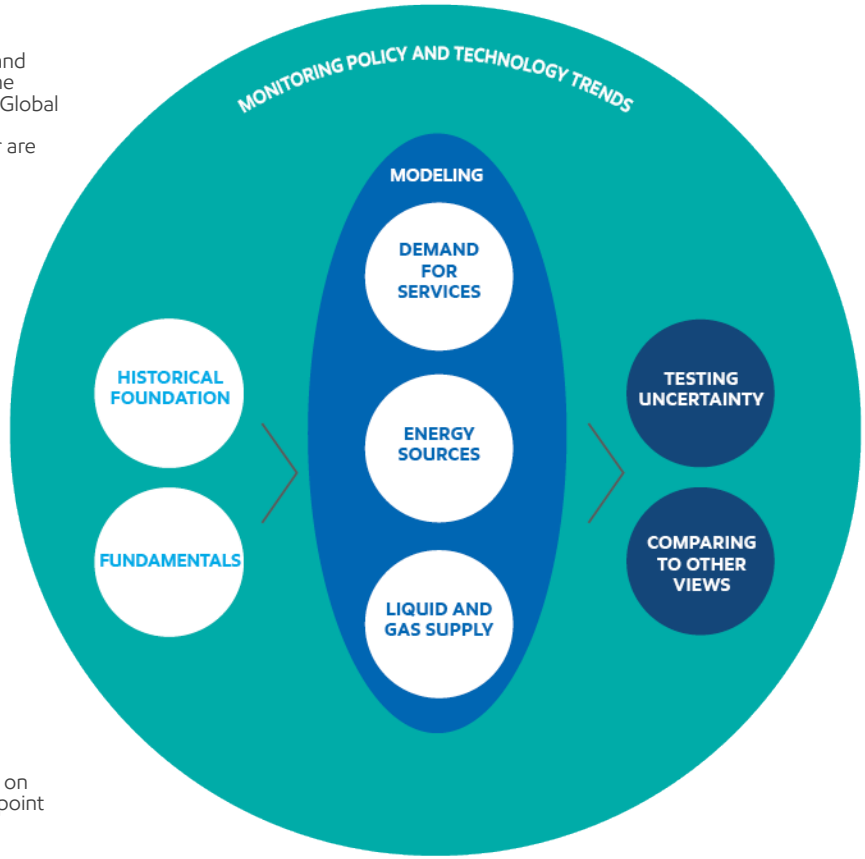
HISTORICAL FOUNDATION[11]
We use energy demand data from the International Energy Agency's (IEA's) World Energy Statistics and Balances data service and other credible third-party sources as the historical basis for the *Outlook*. For liquids supply, we use S&P Global Platts data as the historical basis. For natural gas, historical production and pipeline flows are based upon Wood Mackenzie, IHS, JODI Gas, S&P Global Platts (Eclipse) and other objective third-party sources; historical LNG production and trade flows are based upon IHS Markit (Waterborne) data. In this report, data for periods from 2017 and earlier are considered historical, while data for 2018 and later are ExxonMobil's modeled projections of expected energy demand, supply and trends through 2040.

FUNDAMENTALS[11]
Because population and living standards drive energy demand, we compile demographic information and model economic trends for about 100 regions covering the world. The sources for historical data are primarily the U.N., World Bank, IMF and IHS. Estimates of future population are compiled from the U.N. and World Bank. We model economic trends (e.g., GDP) based on respected third-party views and ExxonMobil's own analysis.

DEMAND FOR SERVICES[12]
The work on fundamentals and data from the historical foundation, along with consumer preferences, form the basis to project energy demand across 15 sectors covering needs for personal mobility, residential energy, production of steel, cement and chemicals, plus many others.

ENERGY SOURCES[12]
We match the demand for energy services with about 20 types of energy (e.g., natural gas), taking into account the current use of each type of energy and the potential evolution of technology, policies, infrastructure and more.

LIQUID AND NATURAL GAS SUPPLY[12]
To meet the global demand for liquid fuels and natural gas, we project oil and gas production from key producing countries/regions. For natural gas, we also project trade flows via pipeline and liquefied natural gas (LNG).



TESTING UNCERTAINTY
Sensitivities (i.e., changes to our base assumptions) are used to assess variations in our assumptions and their potential impact on our projections. These sensitivities are created to test alternative viewpoints from our *Outlook*. They do not represent our viewpoint or the likelihood of these alternatives, but can provide context to our analysis.

COMPARING TO OTHER VIEWS
We also compare the views and projections in our *Outlook* to a variety of publicly available third-party scenarios. These external model projections, formulated by credible sources within and outside of the oil and gas industry, also provide context to assess our modeling approaches and our perspective of future trends.

Glossary

Assessed 2°C scenarios: Technology and policy pathways associated with various climate stabilization targets (e.g., 450, 550 ppm CO_2 equivalent or CO_2e) from a comprehensive multi-model study coordinated by the Energy Modeling Forum 27 (EMF27)[6] at Stanford University[3], partially in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

CCS: Carbon capture and storage is a set of technologies to capture CO_2 and inject it into carefully selected geological formations for safe, secure and permanent storage. CCS is recognized as a key option for reducing CO_2 emissions.

CCU: Carbon capture and utilization is a set of technologies to capture CO_2 and utilize it to make useable products and services.

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.

Electric vehicle (BEV): A type of light-duty vehicle that uses an electric motor exclusively. The motor is powered by a rechargeable electric battery.

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.

Heavy-duty vehicle (HDV): A classification of road vehicles, primarily for commercial use, that include light, medium and heavy trucks, and buses. Heavy-duty fuel demand also includes other unclassified road fuel demand, such as 3-wheel vehicles.

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 liquid hydrocarbon fuel including propane, butane and other similar hydrocarbons with low molecular weight.

Liquids: An energy classification that includes oil, liquid biofuels (such as ethanol and biodiesel) and derived liquids (e.g., gas-to-liquids)

Natural gas: An energy classification that includes natural gas (primarily methane) and synthetic gas (e.g., from coal-to-gas). Natural gas demand includes flared gas.

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.

Oil: Oil supply includes crude oil (such as that coming from conventional, tight oil, deepwater and oil sands developments), condensate and natural gas liquids. Oil demand includes products such as gasoline, diesel, naphtha, kerosene/jet fuel, fuel oil, ethane, LPG, lubricants, asphalt, pet coke and refinery gas produced in oil refineries, natural gas processing plants or derived liquids plants (e.g., gas-to-liquids). Oil demand also includes crude oil and condensate that is used directly (e.g., for electricity generation). Oil excludes liquid biofuels.

Organisation for Economic Co-operation and Development (OECD): A forum for about 36 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. In this Outlook, **OECD** is referring to the 36 nations that are members of the forum; **Non-OECD** is a term used collectively for countries other than the 36 OECD nations.

"Other [geography]" / "Rest of [geography]": Used in chart labels to cover the remaining geography referenced less any regions or countries independently plotted and/or represented on the chart.

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.

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) consumed as a fuel or used as a feedstock (i.e., 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., 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. Primary energy does not include electricity, market heat or hydrogen, which are secondary energy types reflecting conversion /production from primary energy sources.

Secondary energy: Energy types, including electricity, market heat and hydrogen, 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.

Glossary (continued)

Unit	Description	Unit Type	Approximate conversion 1 QUAD =
Quadrillion BTU (QUAD) (1)	Quadrillion (10^{15}) British thermal units	Energy	1
Exajoule	Exa (10^{18}) joules	Energy	1.05
MBDOE (2)	Million (10^{6}) barrels per day oil equivalent	Energy	0.49
TWh	Tera (10^{12}) watt-hours	Energy	293
BCFD	Billion (10^{9}) cubic feet per day	Gas volume	2.9
TCF	Trillion (10^{12}) cubic feet	Gas volume	1.06
GW	Giga (10^{9}) watts	Power	N/A
Billion Tonnes CO_2 (3)	Billion (10^{9}) metric tons energy-related CO_2 emissions	Emissions	N/A

Table notes:

(1) For oil products, energy content is based on the specific energy density of each product (e.g., gasoline, diesel, LPG, etc.).

(2) MBDOE - Oil products are reported in physical barrels; all other energy types are reported on an oil-equivalent energy basis.

(3) CO_2 emissions from the combustion of fossil fuels.

In the *2019 Energy Outlook*, the combustion of biofuels is assumed to have zero net CO_2 emissions (i.e., CO_2 emissions from combustion exactly balances against the photosynthetic update of CO_2 in the growth of biomass used in biofuels), consistent with traditional biomass. This change is intended to bring estimation of energy-related CO_2 emissions from biofuels in line with the method used for other fuel types and is consistent with the methodology used by the IEA. Previous *Outlooks* attributed to biofuels the net carbon emissions over the full land-use cycle.

Update:

The chart on page 6, depicting the Human Development Index, was updated on September 11th, 2019. The x-axis is now shifted to the left. The relative depiction of the various countries, their HDI, their energy consumption and the relation between progress and energy consumption remains unchanged.

Publication footnotes:

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

[2] UNEP (2018). The Emissions Gap Report 2018. United Nations Environment Programme, Nairobi, page XIV and XV, http://wedocs.unep.org/bitstream/handle/20.500.11822/26895/EGR2018_FullReport_EN.pdf?sequence=1&isAllowed=y

[3] 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

[4] UNFCC website: https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/ndc-registry

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

[6] 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

[7] 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 as illustrated in this report. 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 various energy types as a means to estimate trends to 2040 indicative of hypothetical 2°C pathways.

[8] Poverty rates by region at $3.20/day in 2011 Purchasing Power Parity pulled from the World Bank's 2018 report on *Poverty and Shared Prosperity*. These rates were applied to 2017 population to estimate population below the poverty line.

[9] IEA, World Energy Outlook 2016, page 290

[10] International Energy Agency, Tracking Clean Energy Progress, Retrieved from https://www.iea.org/tcep/ on July 15, 2019

[11] Historical data profiles for energy demand, liquids and gas supply, demographic and economic trends are based upon publicly available third-party data. The historical data may be converted into different scientific metrics, or aggregated or disaggregated by regions, sectors or fuels where necessary to complete our analysis. Where there are differences, imbalances or gaps in reported historical data among credible third-parties, professional judgment is applied. 2018 is treated as a projection year because analysis and modeling for this report was conducted in 2018 and early 2019 before a comprehensive set of reliable historical data was available for 2018. Historical data compiled from third-party sources can be subject to later revision as new information becomes available.

[12] Proprietary, internally-developed models are used to model future (1) demand for energy services and energy sources, (2) oil and gas production and (3) natural gas trade flows via pipeline and liquefied natural gas. In addition to the historical foundation and projections of fundamental drivers, these proprietary models use our internal assumptions on many variables such as expected efficiency improvements, the pace of deployment of technology advances, costs, consumer preference and much more. Our internal assumptions are informed by our own proprietary data and analysis, publicly available data and the views of credible third-party consultants, academics and think-tanks. Estimates of energy-related CO_2 emissions from the combustion of fossil fuels are derived from the historical and projected energy demand by applying an emissions factor for each fossil fuel type.

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The Outlook for Energy includes Exxon Mobil Corporation's internal estimates of both historical levels and projections of challenging topics such as energy demand, supply, and trends through 2040 based upon internal data and analyses as well as publicly available information from many external sources including the International Energy Agency. Separate from ExxonMobil's analysis, we include a number of third-party scenarios such as the EMF 27 scenarios and the IEA's Sustainable Development Scenario. Third-party scenarios discussed in this report reflect the modeling assumptions and outputs of their respective authors, not ExxonMobil, and their use and inclusion herein is not an endorsement by ExxonMobil of their likelihood or probability. Work on the Outlook and report was conducted during 2018 and the first half of 2019. The report contains forward looking statements, including projections, targets, expectations, estimates and assumptions of future behaviors. Actual future conditions and results (including energy demand, energy supply, the growth of energy demand and supply, the impact of new technologies, the relative mix of energy across sources, economic sectors and geographic regions, imports and exports of energy) could differ materially due to changes in economic conditions, the ability to scale new technologies on a cost-effective basis, unexpected technological developments, the development of new supply sources, changes in law or government policy, political events, demographic changes and migration patterns, trade patterns, the development and enforcement of global, regional or national mandates, and other factors discussed herein and under the heading "Factors Affecting Future Results" in the Investors section of our website at www.exxonmobil.com.