



BP Energy Outlook 2019 edition



The Energy Outlook explores the forces shaping the global energy transition out to 2040 and the key uncertainties surrounding that transition

The Outlook considers a number of different scenarios. These scenarios are not predictions of what is likely to happen or what BP would like to happen. Rather, they explore the possible implications of different judgements and assumptions by considering a series of “what if” experiments. The scenarios consider only a tiny sub-set of the uncertainty surrounding energy markets out to 2040; they do not provide a comprehensive description of all possible future outcomes.

For ease of explanation, much of the Outlook is described with reference to the ‘Evolving transition’ scenario. But that does not imply that the probability of this scenario is higher than the others. Indeed, the multitude of uncertainties means the probability of any one of these scenarios materializing exactly as described is negligible.

The Energy Outlook is produced to aid BP’s analysis and decision-making, and is published as a contribution to the wider debate. But the Outlook is only one source among many when considering the future of global energy markets. BP considers the scenarios in the Outlook, together with a range of other analysis and information, when forming its long-term strategy.



Welcome to the 2019 edition of BP's Energy Outlook

The outlook facing major energy providers, like BP, is both challenging and exciting.

One of the biggest challenges of our time is a dual one: the need to meet rising energy demand while at the same time reducing carbon emissions.

The emissions-reduction side of this dual challenge will mean shifting to a lower-carbon energy system, as the world seeks to move to a pathway consistent with meeting the climate goals outlined in the Paris Agreement. Much more progress and change is needed on a range of fronts if the world is to have any chance of moving on to such a pathway.

Meeting the other side of the dual challenge will require many forms of energy to play a role. There's a strong correlation between human development and energy consumption – and our analysis of this relationship in this year's Outlook highlights the

need for much more energy to meet demand as prosperity rises.

There are many other challenges facing our industry as the global energy system evolves. The centre of gravity of energy demand is shifting, with the expanding middle classes in Asia accounting for much of the growth in global GDP and energy consumption over the next 20 years. The pattern of energy supply is also changing, with the shale revolution catapulting the US to pole position as the world's largest producer of oil and gas, and the rapid growth of liquefied natural gas (LNG) transforming how natural gas is transported and traded around the globe. Meanwhile, the way in which energy is consumed is changing in real time, as the world electrifies and energy increasingly becomes part of broader services that are bought and sold in ever more competitive and efficient digital markets.

The challenge is to understand, adapt and ultimately thrive in this changing energy landscape. Along with these challenges, come opportunities – and that's what makes this a really exciting time for our industry. Billions of people are being lifted out of low incomes, helping to drive economic growth and the demand for energy. New technologies are revolutionizing the way in which that energy is produced, transported and consumed. And the transition to a lower-carbon energy system is opening up a wide range of business possibilities.

This year's Energy Outlook provides fresh insight into these trends and many more. The value of the Outlook is not in trying to predict the future. Any such attempt is doomed to fail – the uncertainty surrounding the energy transition is here to stay. Rather the value of the Energy Outlook is in providing a structure and discipline

to our thinking and decision-making. It helps us gauge the range of uncertainties, judge how the risks can be managed, and determine how best to encourage change that puts the world on a more positive and sustainable path. Ultimately, we are all part of the energy transition and the decisions all of us make today can shape the future for many years to come.

The Energy Outlook plays an important role in helping to inform and shape our strategic decision-making in BP. I hope you find this year's Outlook a useful contribution to your own discussions and thinking.

Bob Dudley
Group chief executive

The demand for energy is set to increase significantly driven by increases in prosperity in the developing world

Key points

- ▶ The *Energy Outlook* considers different aspects of the energy transition and the key issues and uncertainties these raise.
- ▶ In all the scenarios considered, world GDP more than doubles by 2040 driven by increasing prosperity in fast-growing developing economies.
- ▶ In the Evolving transition (ET) scenario this improvement in living standards causes energy demand to increase by around a third over the Outlook, driven by India, China and Other Asia which together account for two-thirds of the increase.
- ▶ Despite this increase in energy demand, around two-thirds of the world's population in 2040 still live in countries where average energy consumption per head is relatively low, highlighting the need for 'more energy'.
- ▶ Energy consumed within industry and buildings accounts for around three-quarters of the increase in energy demand.
- ▶ Growth in transport demand slows sharply relative to the past, as gains in vehicle efficiency accelerate. The share of passenger vehicle kilometres powered by electricity increases to around 25% by 2040, supported by the growing importance of fully-autonomous cars and shared-mobility services.

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- ▶ The world continues to electrify, with around three-quarters of the increase in primary energy absorbed by the power sector.
 - ▶ Renewable energy is the fastest growing source of energy, contributing half of the growth in global energy supplies and becoming the largest source of power by 2040.
 - ▶ Demand for oil and other liquid fuels grows for the first part of the Outlook before gradually plateauing.
 - ▶ The increase in liquids production is initially dominated by US tight oil, but OPEC production subsequently increases as US tight oil declines.
 - ▶ Natural gas grows robustly, supported by broad-based demand and the increasing availability of gas, aided by the continuing expansion of liquefied natural gas (LNG).
 - ▶ Global coal consumption is broadly flat, with falls in Chinese and OECD consumption offset by increases in India and Other Asia.
 - ▶ In the Evolving transition scenario, carbon emissions continue to rise, signalling the need for a comprehensive set of policy measures to achieve 'less carbon'.
 - ▶ The *Outlook* considers a range of alternative scenarios, including the need for 'more energy', 'less carbon' and the possible impact of an escalation in trade disputes.

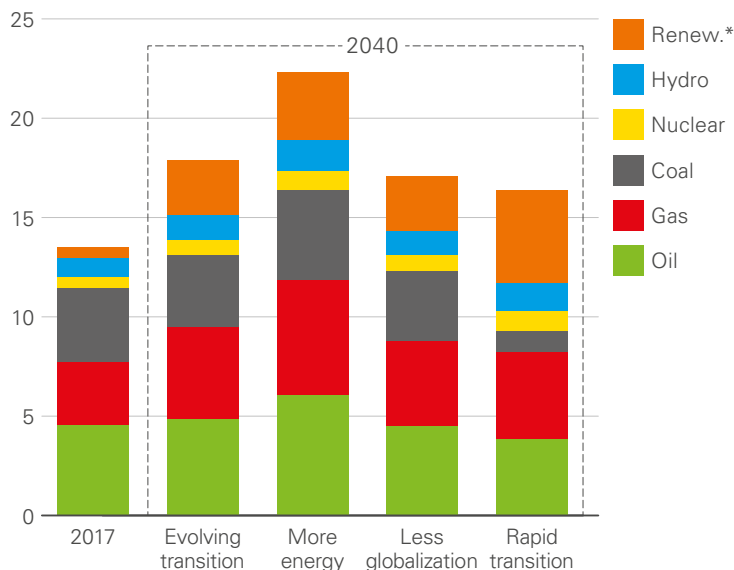
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Overview

The *Energy Outlook* considers a range of scenarios to explore different aspects of the energy transition

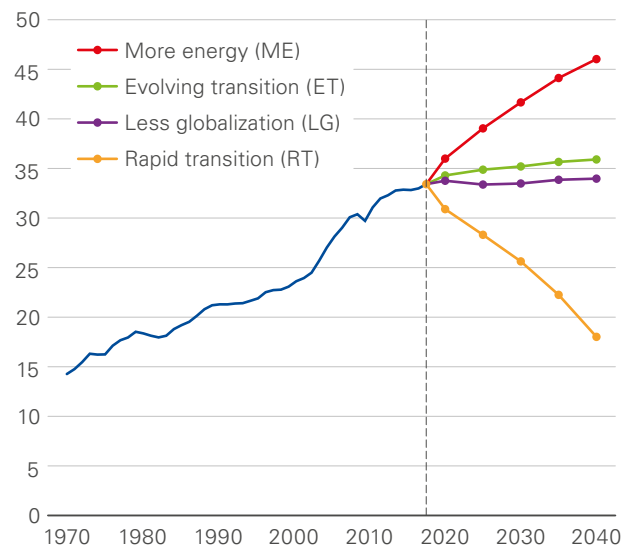
Primary energy consumption by fuel

Billion toe



CO₂ emissions

Gt of CO₂



*Renewables includes wind, solar, geothermal, biomass, and biofuels. For full list of data definitions see p138

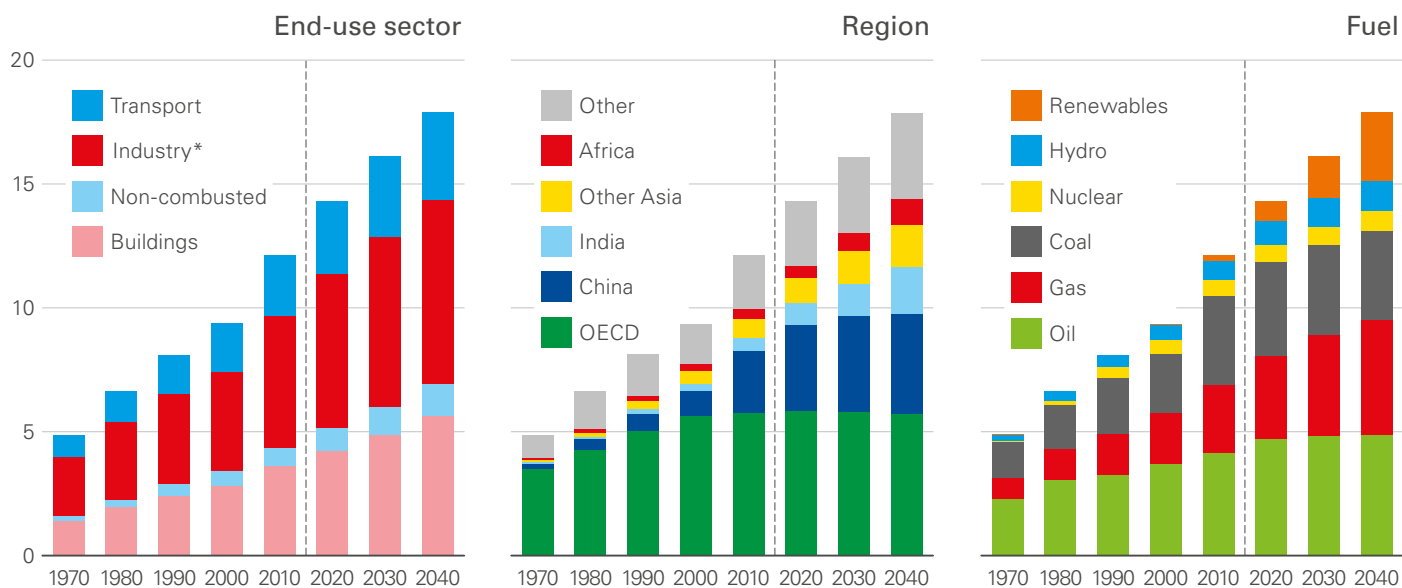
Key points

- ▶ The *Energy Outlook* considers a range of scenarios to explore different aspects of the energy transition. The scenarios have some common features, such as ongoing economic growth and a shift towards a lower-carbon fuel mix, but differ in terms of policy, technology or behavioural assumptions.
- ▶ In what follows, the beginning of each text page (unless stated otherwise) highlights features of the energy transition common across all scenarios considered. For ease of exposition, much of the subsequent description and text boxes are based on the Evolving transition (ET) scenario, which assumes that government policies, technology and social preferences continue to evolve in a manner and speed seen over the recent past.
- ▶ Some scenarios focus on specific fuels or policies, e.g. a possible ban on single-use plastics (pp 34-35). Others focus on impact of possible changes in behaviour, e.g. an escalation in trade disputes (pp 72-75) or major oil producers reforming their economies faster-than-expected (pp 88-89). The Outlook also considers the dual challenge facing the energy system: the need for 'more energy' (pp 22-23) and 'less carbon' (pp 24-25), including the contribution reducing carbon emissions in different sectors of the energy system – transport (pp 48-51), power (pp 58-61) and industry and buildings (pp 38-41) – can make to achieving the Paris climate goals.

The *Outlook* considers the energy transition through three different lenses: sectors, regions and fuels

Primary energy demand

Billion toe



*Industry excludes non-combusted use of fuels

Key points

- ▶ The *Energy Outlook* considers the energy transition from three different perspectives each of which helps to illuminate different aspects of the transition: the sectors in which energy is used; the regions in which it is consumed and produced; and the consumption and production of different fuels.
- ▶ In the ET scenario, global energy demand grows by around a third by 2040 – a significantly slower rate of growth than in the previous 20 years or so.
- ▶ Growth in energy consumption is broad-based across all the main sectors of the economy, with industry and buildings accounting for three-quarters of the increase in energy demand (Sectors pp 28-61).
- ▶ By region, all of the growth in energy demand comes from fast-growing developing economies, led by India and China. Differing regional trends in energy production lead to noticeable shifts in global energy trade flows (Regions pp 64-75).
- ▶ Renewable energy is the fastest growing source of energy, accounting for around half of the increase in energy. Natural gas grows much faster than either oil or coal. The growing abundance of energy supplies plays an increasing role in shaping global energy markets (Fuels pp 78-109).

Global backdrop

GDP, prosperity and energy intensity

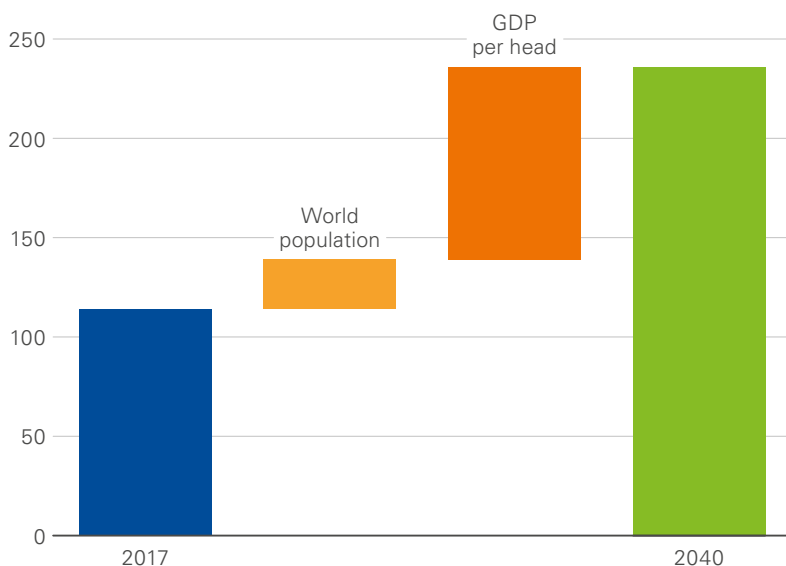
Alternative scenario: More energy

Dual challenge: More energy, less carbon

Global economic growth is driven by increasing prosperity in developing economies, led by China and India

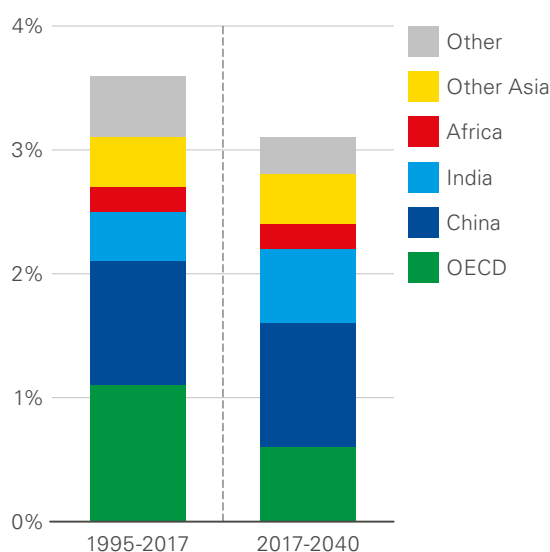
Increase in global GDP, 2017-2040

Trillion \$US PPP



Global GDP growth and regional contributions

% per annum



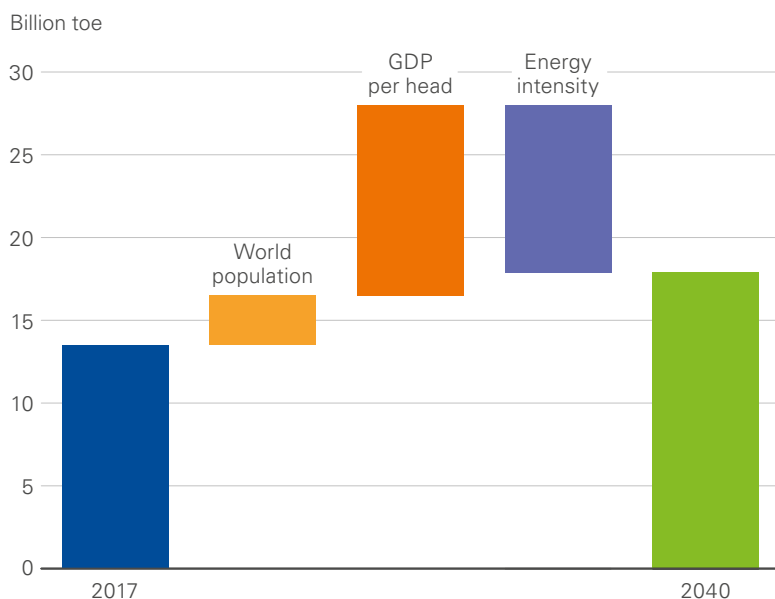
Key points

Billions of people move from low-incomes driving global economic growth and energy demand

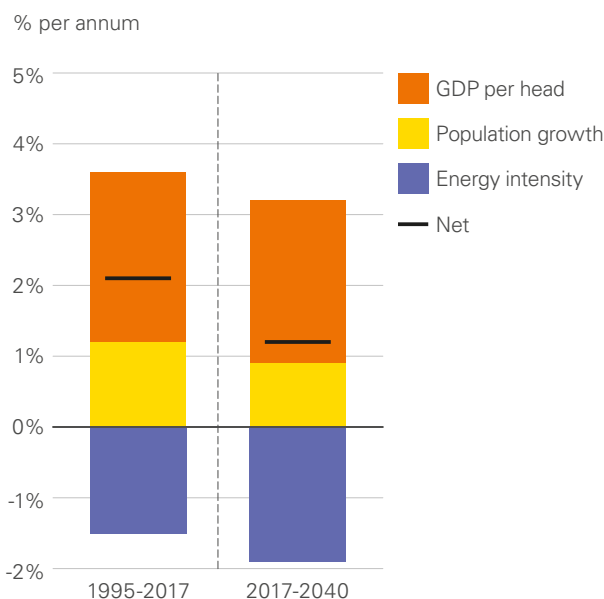
- ▶ The world economy continues to grow, driven by increasing prosperity in the developing world.
- ▶ In the ET scenario, global GDP grows around 3¼% p.a. (on a Purchasing Power Parity basis) – a little weaker than average growth over the past 20 years or so.
- ▶ Global output is partly supported by population growth, with the world population increasing by around 1.7 billion to reach nearly 9.2 billion people in 2040.
- ▶ But the vast majority of world growth is driven by increasing productivity (i.e. GDP per head), which accounts for almost 80% of the global expansion and lifts more than 2½ billion people from low incomes. The emergence of a large and growing middle class in the developing world is an increasingly important force shaping global economic and energy trends.
- ▶ Developing economies account for over 80% of the expansion in world output, with China and India accounting for around half of that growth.
- ▶ Africa continues to be weighed down by weak productivity, accounting for almost half of the increase in global population, but less than 10% of world GDP growth.

Higher living standards drive increases in energy demand, partly offset by substantial gains in energy intensity

Increase in primary energy demand, 2017-2040



Contributions to primary energy demand growth



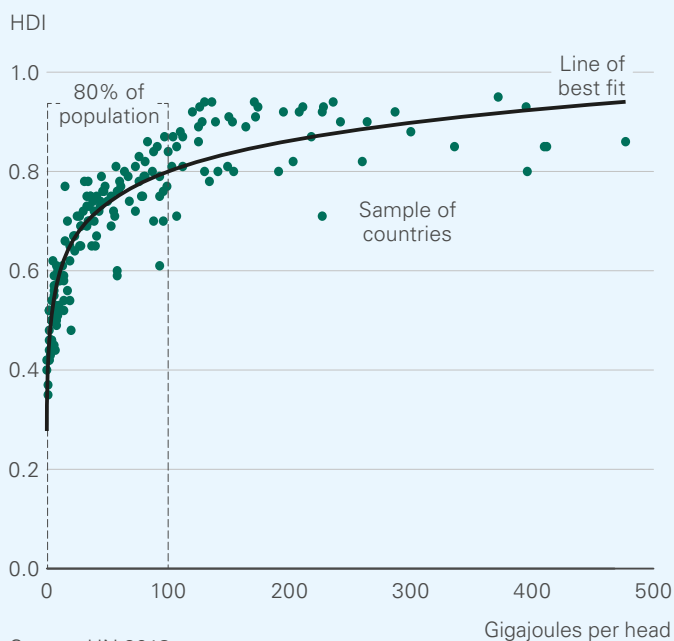
Key points

- ▶ Expansion in global output and prosperity drives growth in global energy demand.
- ▶ Energy consumption in the ET scenario increases by around a third over the Outlook. As with GDP growth, the vast majority of this increase stems from increasing prosperity, as billions of people move from low to middle incomes, allowing them to increase substantially their energy consumption per head.
- ▶ The overall growth in energy demand is materially offset by declines in energy intensity (energy used per unit of GDP) as the world increasingly learns to produce more with less: global GDP more than doubles over the Outlook, but energy consumption increases by only a third.
- ▶ Global energy grows at an average rate of 1.2% p.a. in the ET scenario, down from over 2% p.a. in the previous 20 years or so. This weaker growth reflects both slower population growth and faster improvements in energy intensity.
- ▶ Despite significant growth in prosperity and energy consumption over the next 20 years, a substantial proportion of the world's population in the ET scenario still consumes relatively low levels of energy in 2040. The need for the world to produce 'more energy' as well as 'less carbon' is discussed in pp 22-25.

Alternative scenario: More energy

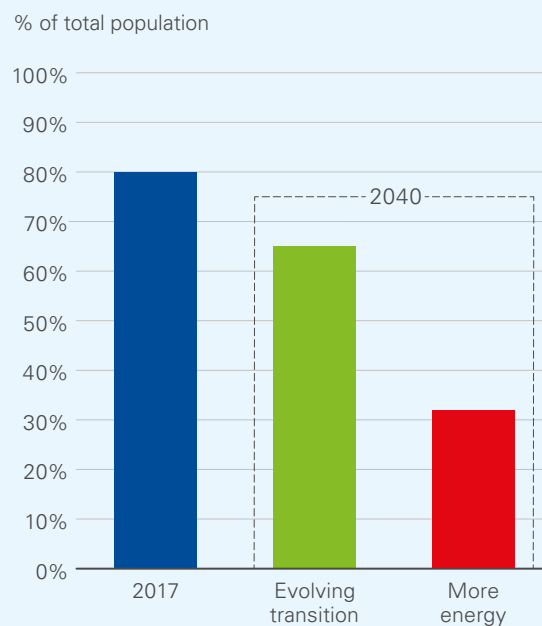
Alternative scenario: the world needs 'more energy' to allow global living standards to continue to improve

Human development index and energy consumption per head, 2017



Source: UN 2018

Share of world population consuming less than 100 Gigajoules per head



Key points

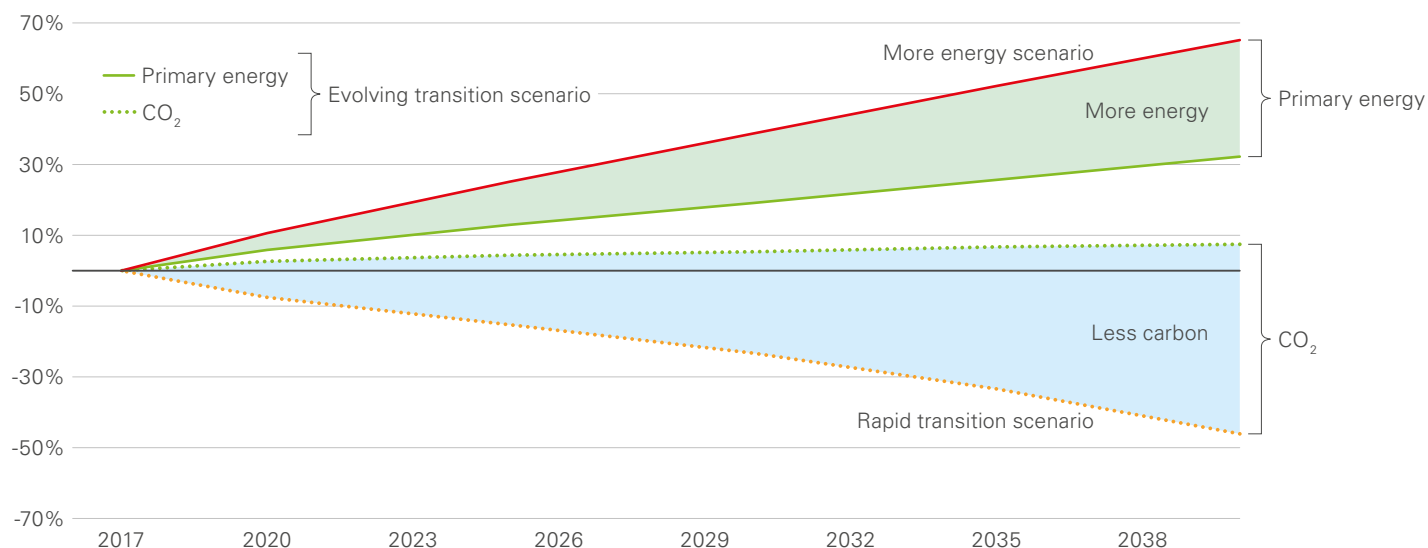
- ▶ There is a strong link between human progress and energy consumption.
 - ▶ The United Nation's Human Development Index (HDI) suggests that increases in energy consumption up to around 100 Gigajoules (GJ) per head are associated with substantial increases in human development and well-being, after which the relationship flattens out.
 - ▶ Around 80% of the world's population today live in countries where average energy consumption is less than 100 GJ per head. In the ET scenario, this proportion is still around two-thirds even by 2040. In the alternative 'More energy' scenario this share is reduced to one-third by 2040.
- This requires around 25% more energy by 2040 – roughly equivalent to China's energy consumption in 2017.
- ▶ This assumes that countries in which energy consumption is much greater than 100 GJ/per head do not economize on their energy use. If all those countries reduced average consumption levels to the EU average in 2040 (around 120 GJ/per head), this would provide almost the entire energy required.
 - ▶ Improving energy efficiency in countries which use disproportionate amounts of energy is likely to be key to solving the dual challenge of providing 'more energy and less carbon' (pp 22-25).

80% of the world's population live in countries where average energy consumption is less than 100 GJ per head

The global energy system faces a dual challenge: the need for 'more energy and less carbon'

Primary energy demand and carbon emissions

Cumulative growth rate, 2017 = 0%



Key points

- ▶ The global energy system faces a dual challenge: the need for 'more energy and less carbon'.
- ▶ The ET scenario is not consistent with achieving either of these challenges:
 - energy demand increases by a third, but two-thirds of the world population in 2040 live in countries in which average energy consumption is still less than 100 GJ per head;
 - CO₂ emissions from energy use continue to edge up, increasing by almost 10% by 2040, rather than falling substantially.
- ▶ The 'More energy' scenario represents a half-way step to reducing the proportion of the world's population living in countries where the average level of consumption is below 100 GJ/per head to one-third by 2040.
- ▶ The 'Rapid transition' scenario (see pp 114-117) represents a similar half-way step on carbon emissions: reducing CO₂ emissions by around 45% by 2040, almost half-way to reducing entirely carbon emissions from energy use.

Sectors

Summary

Industry

Non-combusted

Alternative scenario: Single-use plastics ban

Buildings

Alternative scenario: Lower-carbon industry and buildings

Transport

Alternative scenario: Lower-carbon transport

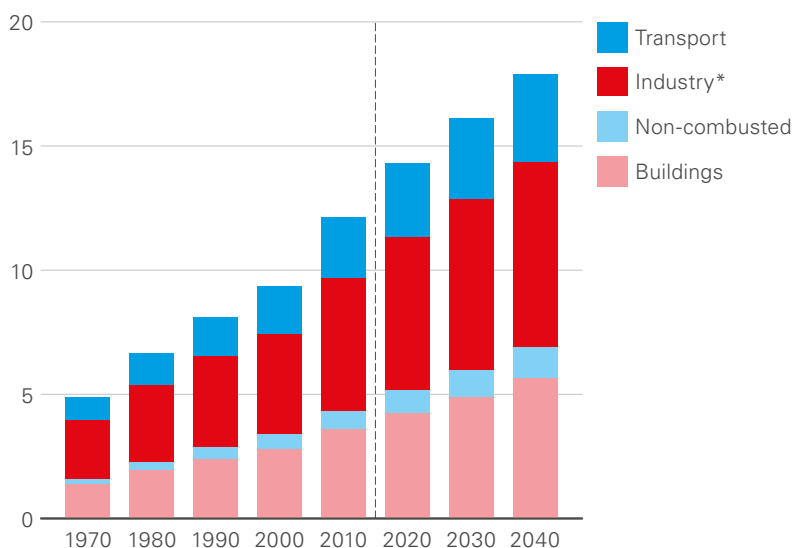
Power

Alternative scenario: Lower-carbon power

Energy demand grows in all sectors, with buildings and non-combusted use increasing in importance

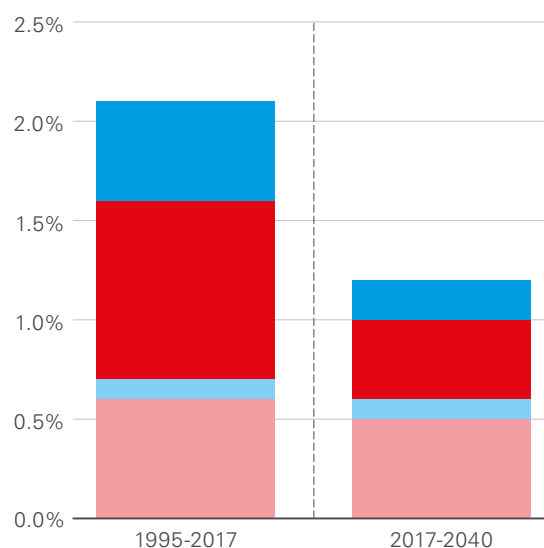
Primary energy consumption by end-use sector[†]

Billion toe



Annual demand growth and sector contributions

% per annum



[†]Primary energy used in power is allocated according to final sector electricity consumption

*Industry excludes non-combusted use of fuels

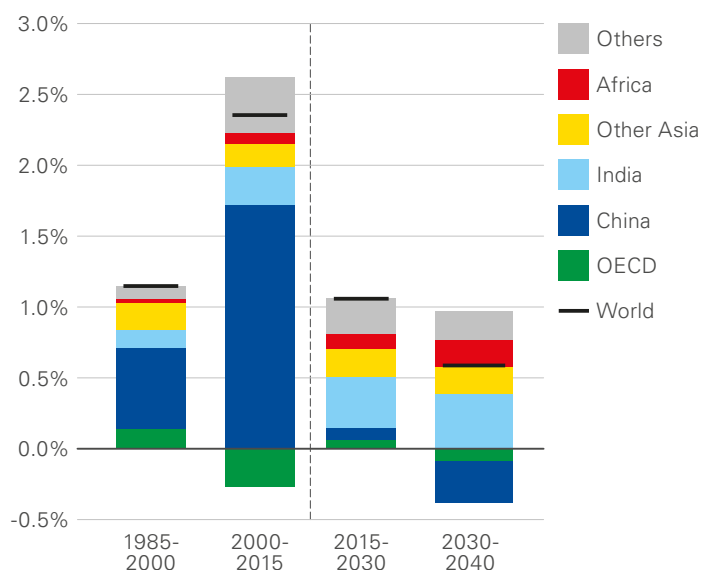
Key points

- ▶ Growth in global energy demand is broad-based across all the main sectors of the global economy. Differing trends in how energy is used and consumed in these sectors has an important bearing on the energy transition.
- ▶ The industrial sector (including the non-combusted use of fuels) currently consumes around half of all global energy and feedstock fuels, with residential and commercial buildings (29%) and transport (21%) accounting for the remainder.
- ▶ In the ET scenario, the growth of energy consumption in all sectors slows as gains in energy efficiency quicken. The slowing in demand growth is most marked in the transport sector – with the growth of transport demand less than half the rate of the previous 20 years – as improvements in vehicle efficiency accelerate (pp 42-43).
- ▶ Growth of energy demand used within industry also slows (pp 30-31). Despite this, the non-combusted use of fuels within industry – particularly as a feedstock in petrochemicals – is the fastest growing source of incremental demand (pp 32-33).
- ▶ The importance of energy used within buildings expands over the Outlook, as growing prosperity in developing economies leads to significant increases in power demand, for space cooling, lighting and electrical appliances (pp 52-55).

The pattern of energy used within industry shifts, driven by the changing role of China

Final energy consumption in industry: Regional shares of growth

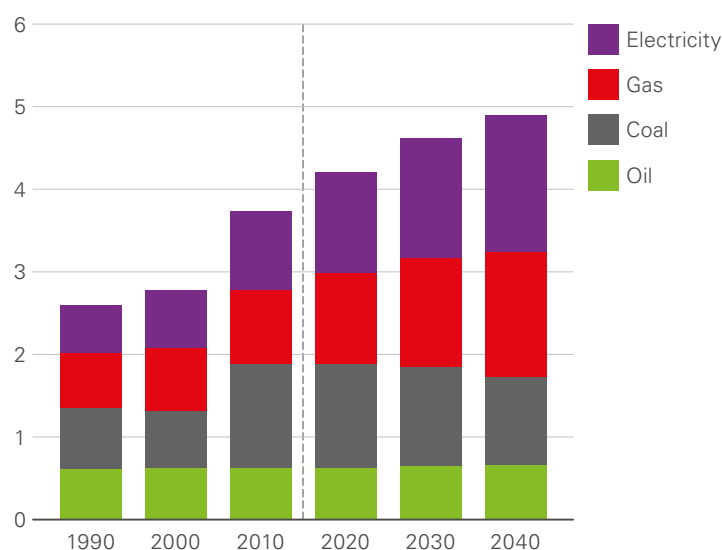
% per annum



Note: Industry excludes non-combusted use of fuels

Final energy consumption in industry: Demand by fuel

Billion toe



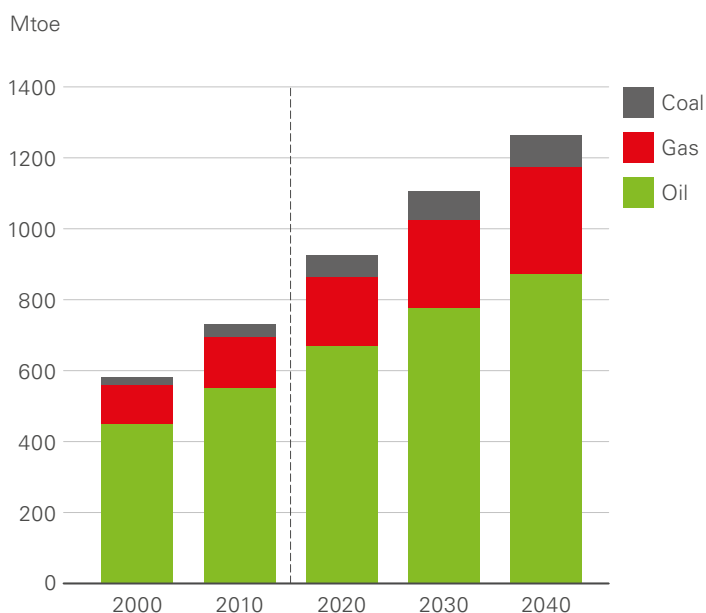
Key points

Growth of energy used in industry shifts from China to other developing countries

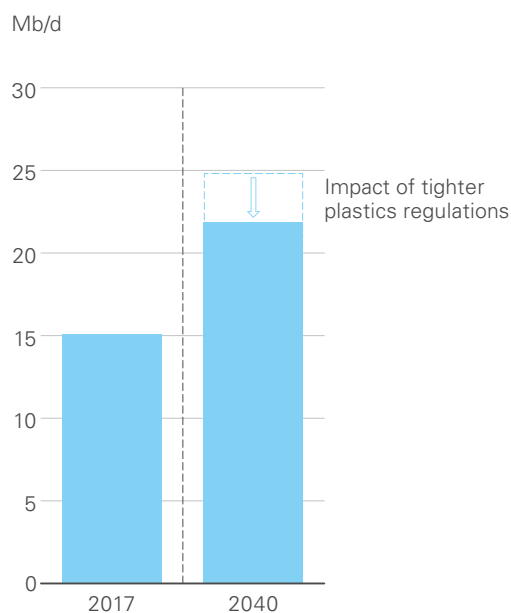
- ▶ The Outlook for industrial energy demand is dominated by the changing energy needs of China (see pp 64-67).
- ▶ After tripling over the past 20 years, Chinese industrial energy demand in the ET scenario peaks in the mid-2020s and gradually declines thereafter. Some of this decline stems from policy efforts to improve the efficiency of existing industries. In addition, it reflects the continuing transition of the Chinese economy away from energy-intensive industrial sectors towards less-intensive service and consumer-facing sectors.
- ▶ The transition in the Chinese economy means much of the growth in industrial production is located outside of China, with India, Other Asia and Africa accounting for around two-thirds of the increase in industrial energy demand over the Outlook.
- ▶ All of the net growth in industrial demand is met by natural gas and electricity, with these fuels accounting for around two-thirds of the energy used in industry by 2040. Coal consumption within industry declines as China, the EU and North America switch to cleaner, lower-carbon fuels, partially offset by growth in India and Other Asia.

Non-combusted use of oil, gas and coal grows robustly, despite increasing regulation on the use of plastics

Non-combusted demand: By source



Non-combusted demand: Oil demand



Key points

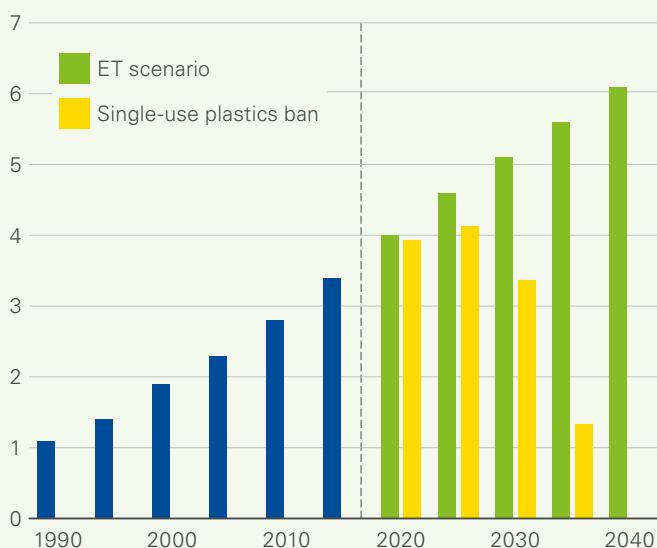
- ▶ The non-combusted use of oil, gas and coal, e.g. as feedstocks for petrochemicals, lubricants and bitumen, grows robustly driven by particularly strong growth in plastics.
- ▶ In the ET scenario, the non-combusted use of fuels grows by 1.7% p.a., accounting for around 10% of the overall growth in energy demand. Oil-based fuels account for around 60% of this growth, followed by natural gas (30%) and coal (10%).
- ▶ The growth of fuels as a feedstock is slower than in the past, largely reflecting the assumption that regulations governing the use and recycling of plastics tighten materially over the next 20 years, including a doubling of recycling rates to around 30%. This reduces the growth in oil demand by around 3 Mb/d relative to a continuation of past trends. (The impact of a worldwide ban on the use of single-use plastics is considered on pp 34-35).
- ▶ Despite increasing regulation, the use of oil as a feedstock is the largest source of oil demand growth over the Outlook (7 Mb/d); the contribution of non-combusted use to the growth of gas and coal demand is much smaller. The non-combusted use of oil accounts for around 18% of total liquids consumption by 2040, compared with 7% for natural gas and 3% for coal.

Alternative scenario: Single-use plastics ban

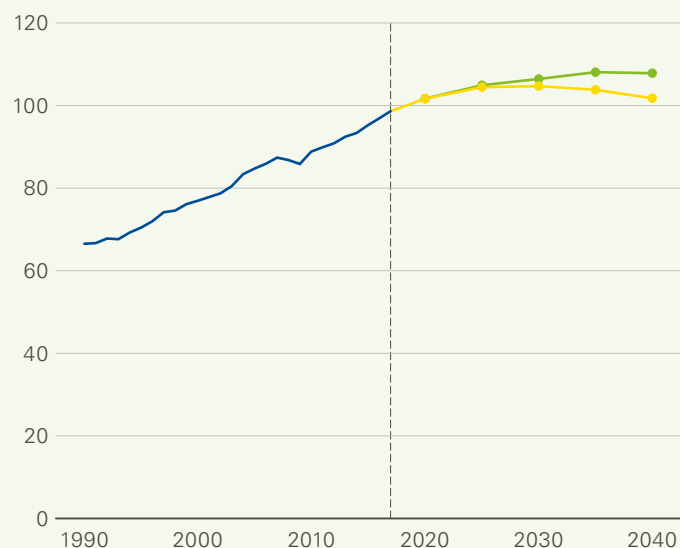
Alternative scenario: increasing environmental concerns lead to a worldwide ban on single-use plastics from 2040

Liquid feedstocks for single-use plastics

Mb/d



Total liquids demand



Key points

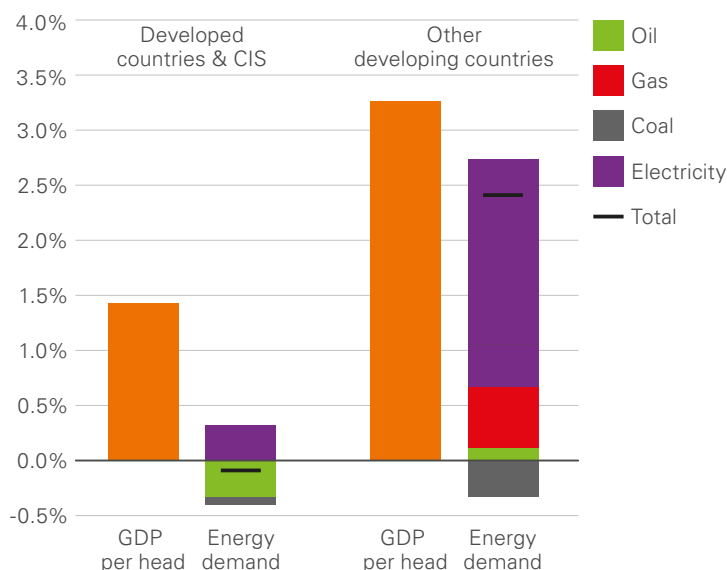
- ▶ The ET scenario assumes that the regulation of plastics tightens more quickly than in the past. But growing concerns about the use of plastics means that regulation of plastics may tighten by even more.
- ▶ The alternative 'Single-use plastics ban' (SUP ban) scenario considers a case in which the regulation of plastics is tightened more quickly, culminating in a worldwide ban on the use of plastics for packaging and other single uses from 2040 onwards. These single-use plastics accounted for just over a third of plastics produced in 2017.
- ▶ In this alternative scenario, the growth in liquid fuels used in the non-combusted sector is reduced to just 1 Mb/d – 6 Mb/d lower than in the ET scenario – and the overall growth of liquids demand is limited to 4 Mb/d, compared with 10 Mb/d in the ET scenario.
- ▶ The scenario does not account for the energy consumed to produce the alternative materials used in place of the single-use plastics, and so represents an upper-bound of the impact on liquid fuels.
- ▶ Indeed, without further advances in these alternative materials and widespread deployment of efficient collection and reuse systems, such a ban could lead to an increase in overall energy demand and carbon emissions, and raise a number of other environmental concerns, such as increasing food waste.

A substantial tightening in the regulation of plastics could significantly reduce the growth of oil demand

Buildings account for over a third of global energy growth, driven by increased power demand in the developing world

Growth of prosperity and energy use in buildings

Annual growth in 2017-2040, % per annum



Final energy consumption in buildings by fuel

Billion toe



Key points

Electricity provides most of the increasing energy used in buildings

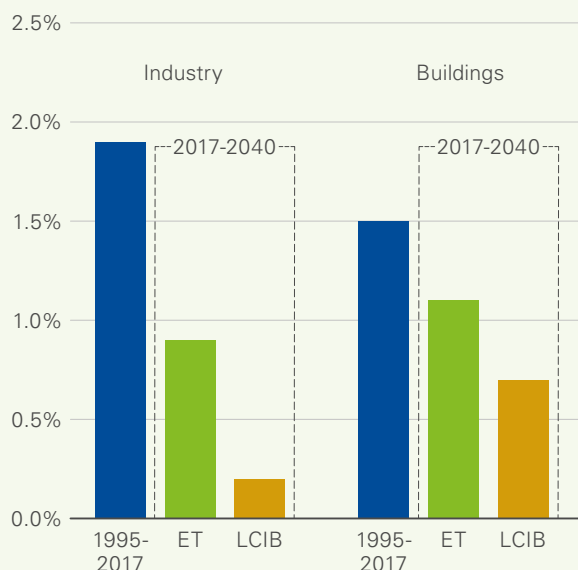
- ▶ The increase in prosperity and expanding middle class in the developing world drives growing use of energy within buildings.
- ▶ In the ET scenario, energy used in buildings grows (1.5% p.a.) more strongly than in industry or transport, with its share of overall energy consumption edging up to around a third by 2040.
- ▶ This growth is driven entirely by developing economies, where improving wealth and living standards allows people to live and work in greater comfort.
- ▶ Energy growth in much of the developed world and CIS essentially flat-lines as increasing activity is offset by efficiency gains.
- ▶ The vast majority of the growth in energy used in buildings over the Outlook is provided by electricity, reflecting greater use of lighting and electrical appliances and the increasing demand for space cooling in much of the developing world (Asia, Africa and the Middle East) as living standards increase.
- ▶ There is also small increase in gas consumption, which gains share from both coal and oil in space heating and cooking.

Alternative scenario: Lower-carbon industry and buildings

Alternative scenario: Lower-carbon industry and buildings, driven by efficiency gains, CCUS and circular economy

Energy demand growth in ET and LCIB scenarios

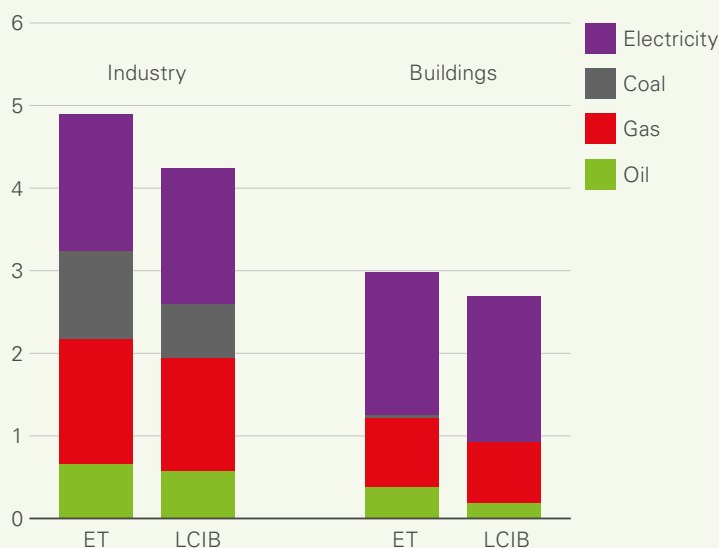
% per annum



Note: Industry does not include non-combusted sector

Industry and buildings fuel mix (2040)

Billion toe



Key points

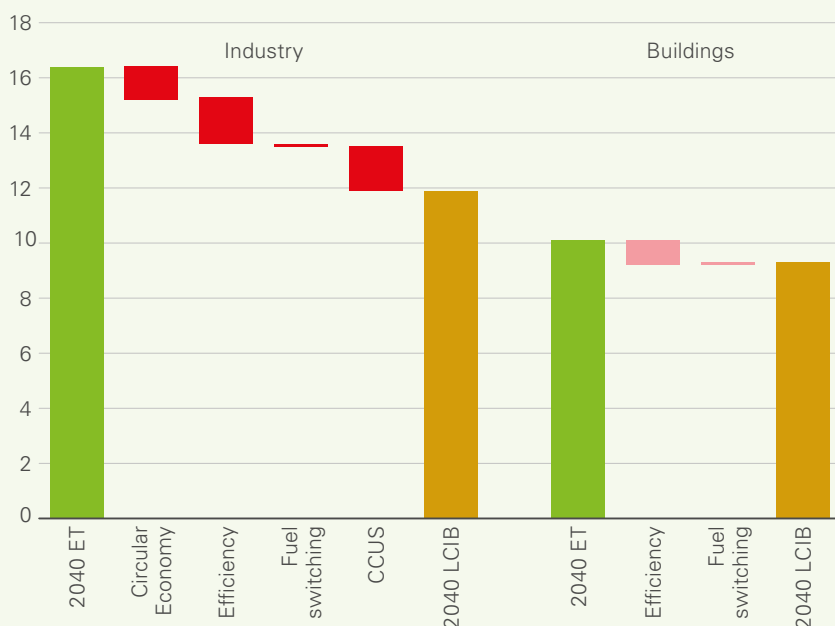
- ▶ In the ET scenario, the growth of energy used in both industry and buildings slows relative to the past, as gains in energy efficiency accelerate. The 'Lower-carbon industry and buildings' (LCIB) scenario considers an even more marked slowing in energy:
 - ▶ for industry, this reflects greater gains in energy efficiency as recent trends in efficiency are accelerated, supported by an expansion of circular economy activities (re-use and recycling) reducing demand for new materials and products;
 - ▶ for buildings, these gains are achieved via a combination of retrofitting existing buildings and stricter regulation of new buildings and electric appliances.
- ▶ Energy use in industry and buildings increases by only 0.3% p.a. in the LCIB scenario, compared with 1.0% p.a. in the ET scenario and 1.8% p.a. over the past 20 years.
- ▶ In addition, a rise in carbon prices in line with that assumed in the Lower-carbon power scenario (pp 58-61) prompts a shift in the fuel mix, particularly in industry, away from coal towards gas and power and increases the use of carbon capture use and storage (CCUS) in the industrial sector.

Industry and buildings are the dominant end-users of global energy and so have an important bearing on the energy transition

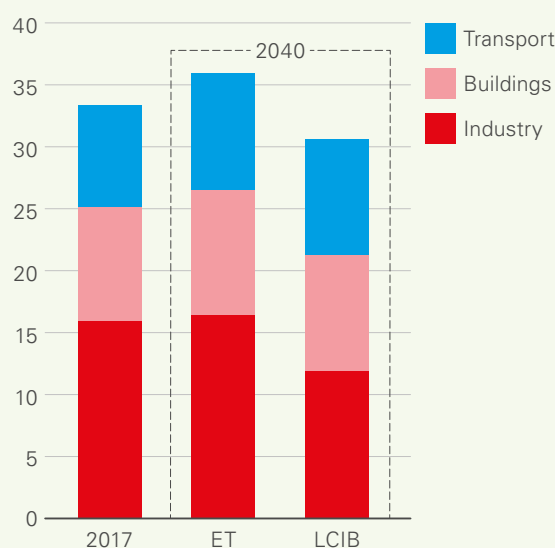
Alternative scenario: Lower-carbon industry and buildings

Carbon emissions fall in the LCIB scenario, largely in industry, driven by efficiency and CCUS

Carbon emissions in industry and buildings

Gt of CO₂

Carbon emissions by sector



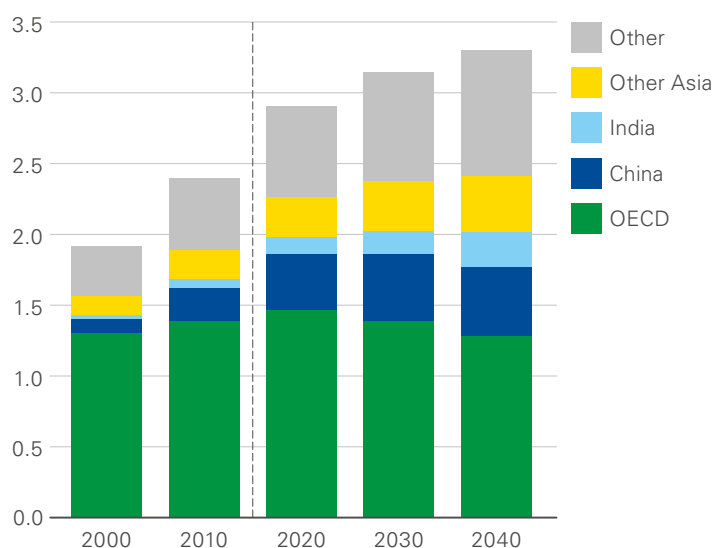
Key points

- ▶ In the LCIB scenario, CO₂ emissions from industry and buildings scenario fall by 15% (3.9 Gt by 2040), compared with an increase of 6% (1.7 Gt) in the ET scenario.
- ▶ The majority of these reductions relative to the ET scenario are concentrated in the industrial sector. These gains are driven by the accelerated efficiency gains and the increased use of CCUS which, in the industrial sector, reaches around 2 Gt by 2040. The reduced demand for new materials and products associated with the increased adoption of circular economy activities also adds to carbon savings in industry.
- ▶ The reduction in carbon emissions from buildings are more limited, and all stem from the efficiency measures applied to retrofitting existing buildings and tighter efficiency regulations for new buildings and appliances.
- ▶ The contribution of fuel switching to the fall in carbon emissions is relatively small in both sectors. This partly stems from the difficulty of switching fuels for some activities, especially high-temperature processes in industry. It also reflects that the benefits of switching from existing fuels into electricity are mitigated without a significant decarbonization of the power sector (see pp 54-57).

Demand for transport services grows strongly, but gains in energy efficiency limit increases in energy used

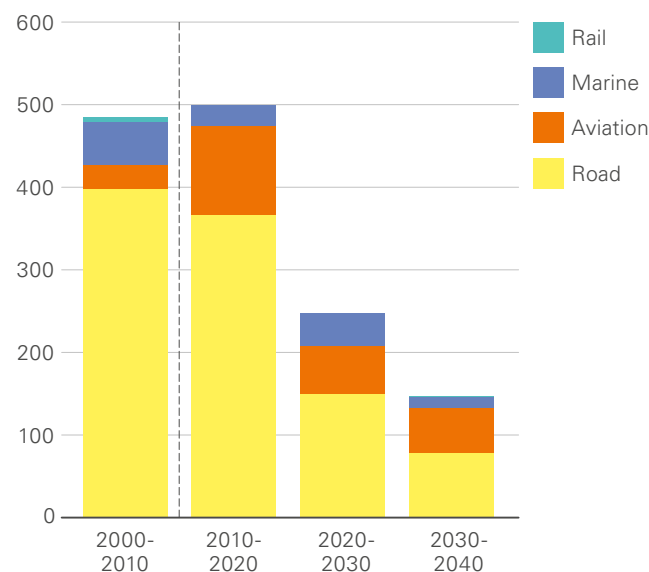
Final energy consumption in transport:
By region

Billion toe



Final energy consumption in transport:
Growth by mode

Mtoe



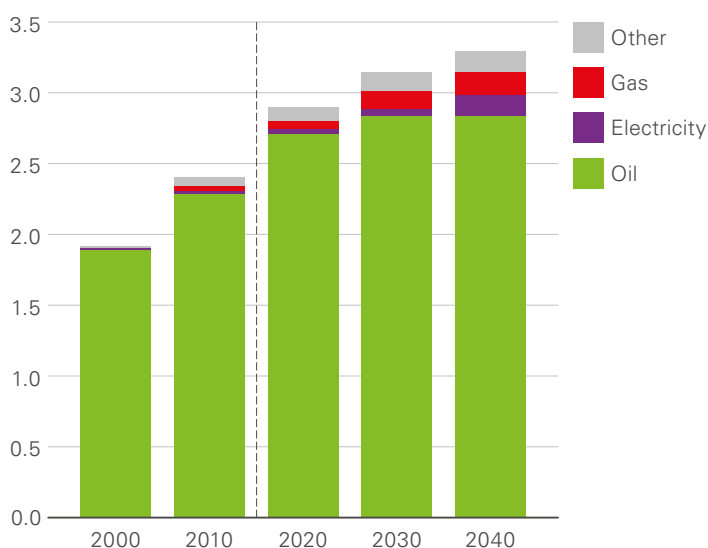
Key points

- ▶ Rapid gains in energy efficiency limit increases in energy used in transportation despite rapid growth in the demand for transport services.
- ▶ In the ET scenario, the demand for transport services almost doubles, but quickening gains in engine efficiency mean that energy consumed increases by only 20%.
- ▶ The growth in energy used in transport is concentrated within developing Asia, which accounts for 80% of the net increase, as rising prosperity increases demand for both the quantity and quality of transport services.
- ▶ The increase in energy consumed across different modes of transport is affected by the pace of efficiency improvements. The efficiency of the average internal-combustion-engine car improves by nearly 50% in the major global car markets; truck efficiency also records substantial gains. As a result, the rate of demand growth in the road sector decelerates significantly, leading the slow-down in overall transport demand growth.
- ▶ In contrast, the scope for further efficiency gains within aviation and marine is more modest. These modes account for nearly half of the increase in energy used in transport in the final decade of the Outlook, even though their combined share of total transport demand today is only 20%.

Transport demand continues to be dominated by oil, despite increasing use of natural gas, electricity and biofuels

Final energy consumption in transport:
Consumption by fuel

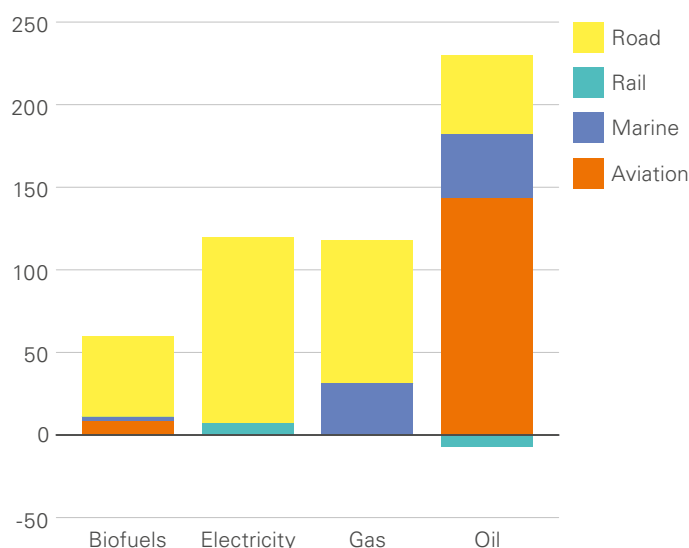
Billion toe



Other includes biofuels, coal and hydrogen

Final energy consumption in transport:
Growth by fuel and mode, 2017-2040

Mtoe



Key points

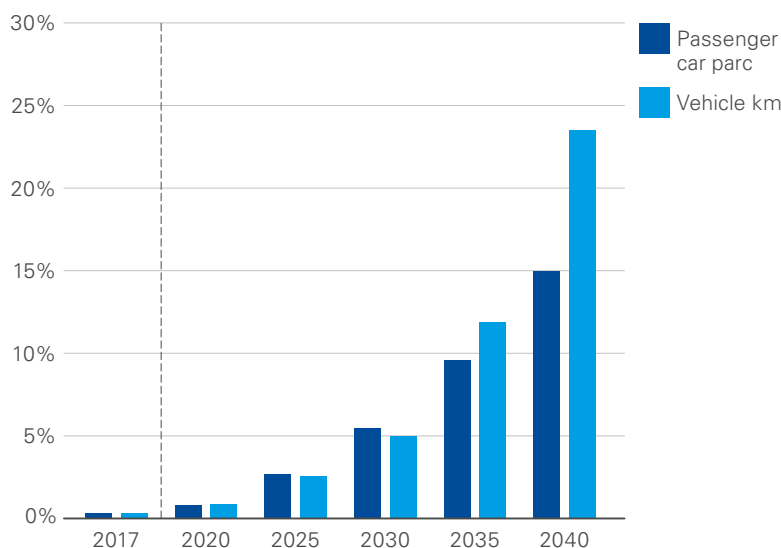
- ▶ The transport sector continues to be dominated by oil, despite increasing penetration of alternative fuels, particularly electricity and natural gas.
- ▶ In the ET scenario, the share of oil within transport declines to around 85% by 2040, down from 94% currently. Natural gas, electricity and biofuels together account for more than half of the increase in energy used in transport, with each providing around 5% of transport demand by 2040.
- ▶ Oil used in transport increases 4 Mb/d (220 Mtoe), with the majority of that demand stemming from increased use in aviation and marine, rather than road transportation.
- ▶ Electricity and natural gas in transportation increase by broadly similar volumes (120 Mtoe), with the increased use of electricity concentrated in passenger cars and light trucks; and the rising demand for natural gas largely within long-distance road haulage and marine.
- ▶ The use of biofuels increases by just under 2 Mb/d (60 Mtoe), predominantly in road transport, with some increase in aviation.
- ▶ An alternative 'Lower-carbon transport' scenario (pp 48-51) considers the scope for greater fuel switching, as well as faster efficiency gains.

Non-oil energy sources account for over half of the increase of energy used in transport

Electric vehicles continue to grow rapidly, with their impact amplified by growth of autonomous vehicles

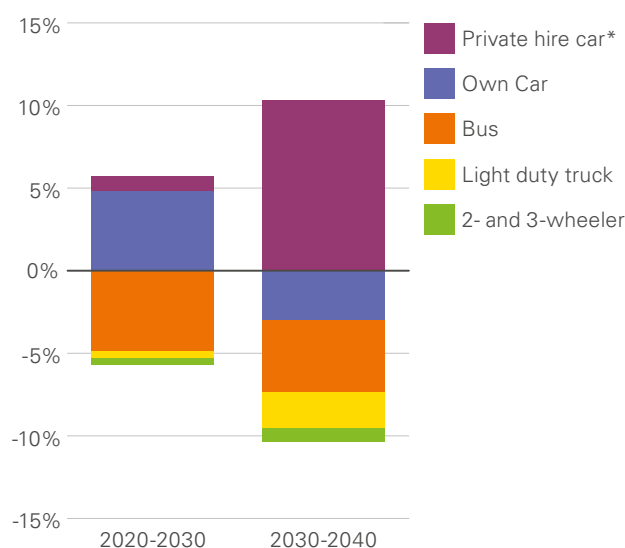
Passenger car parc and vehicle km electrified

Share electrified



Change in the share of road passenger km

Percentage point



*Includes all forms of taxis

Key points

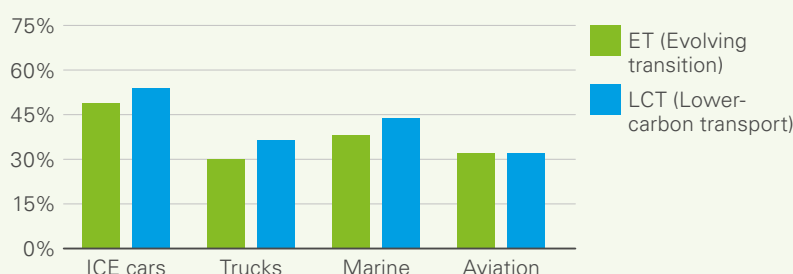
Global prosperity and autonomous vehicles risk increasing congestion

- ▶ Electric vehicles continue to grow rapidly, concentrated within passenger cars, light-duty trucks (LDTs) and public buses.
- ▶ In the ET scenario, the number of electric vehicles reaches around 350 million by 2040, of which around 300 million are passenger cars. This is equivalent to around 15% of all cars and 12% of LDTs.
- ▶ The use of electric passenger cars is amplified by the emergence of autonomous cars (AVs) from the early 2020s offering low-cost, shared-mobility services, predominantly in electric cars. As a result, around 25% of passenger vehicle km are powered by electricity in 2040, even though only 15% of cars are electrified.
- ▶ The rise in global prosperity leads to a shift away from high-occupancy road transport (buses) to private vehicles, reducing the global load factor for road vehicles (i.e. the average number of passengers per vehicle). This trend is compounded in the second half of the Outlook by the falling cost of road travel associated with the growing availability of low-cost shared mobility services using autonomous vehicles.
- ▶ The fall in the global load factor for road vehicles and associated increase in road congestion is a key challenge facing the global transport system over the Outlook.

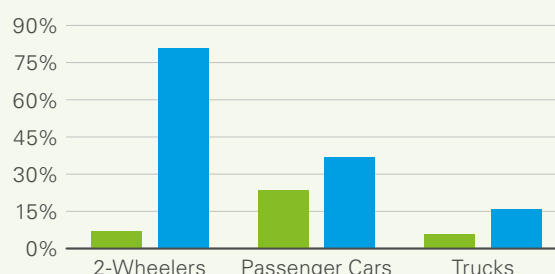
Alternative scenario: Lower-carbon transport

Alternative scenario: a lower-carbon transport sector by increasing efficiency, alternative fuels and shared mobility

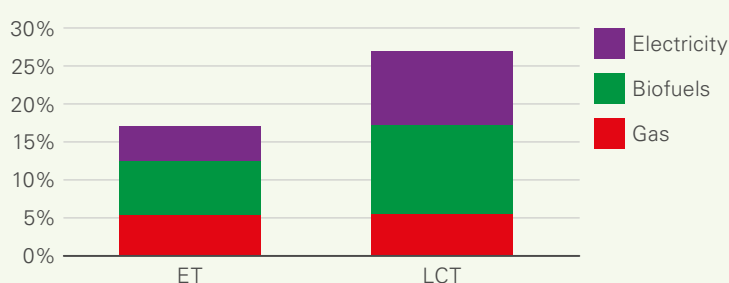
Efficiency improvements 2017-2040 (%)



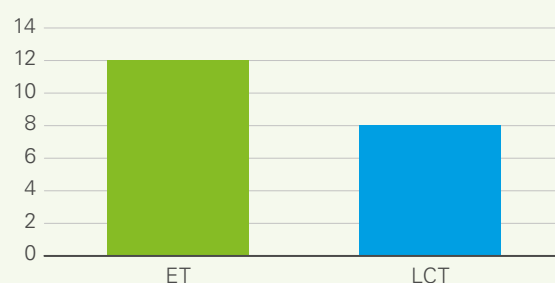
Electrification of vehicle km by 2040 (%)



Share of non-oil road transport by 2040 (%)



Typical car-lifespan (years)



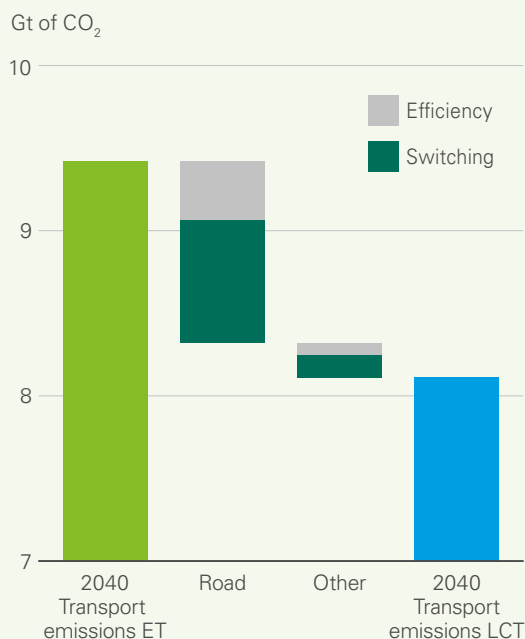
Key points

- ▶ Despite significant increases in vehicle efficiency and electrification, carbon emissions in the transport sector in the ET scenario continue to increase.
- ▶ The alternative 'Lower-carbon transport' (LCT) scenario includes a large number of measures designed to reduce carbon emissions in the transport sector, including:
 - ▶ further tightening in vehicle efficiency standards, such that the average internal-combustion-engine car in 2040 is around 55% more efficient than today; the pace of efficiency gains in new trucks and ships also increases;
 - ▶ increased electrification, including bans on sales of all internal-combustion engine cars in much of the OECD and China by 2040 or soon after; half of global sales of new trucks and buses are electric or hydrogen-powered by 2040;
 - ▶ increased penetration of shared mobility services, including more consumer-friendly 'mini-buses', increasing the share of passenger kilometres which are electrified and helping to arrest some of the decline in the global road 'load factor';
 - ▶ increasing the share of biofuels in road transport in the OECD and China to 20% by 2040 (and to 10% in the rest of the world); similarly in aviation, increase the share of biofuels in jet fuel to 20% in the developed world by 2040;
 - ▶ car scrappage schemes which reduce the typical lifespan of a car from around 12 years to 8 years by 2040, improving the average efficiency of the global car parc and the pace of electrification.

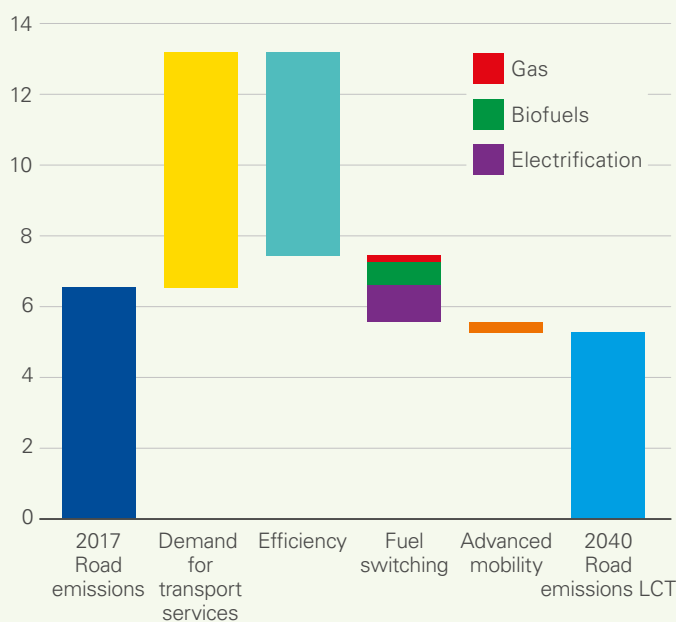
Alternative scenario: Lower-carbon transport

Increasing efficiency, rather than fuel switching, is the main factor causing transport carbon emissions to fall from current levels

Transport emissions in ET and LCT scenarios in 2040



Road emissions in LCT scenario, 2017-2040



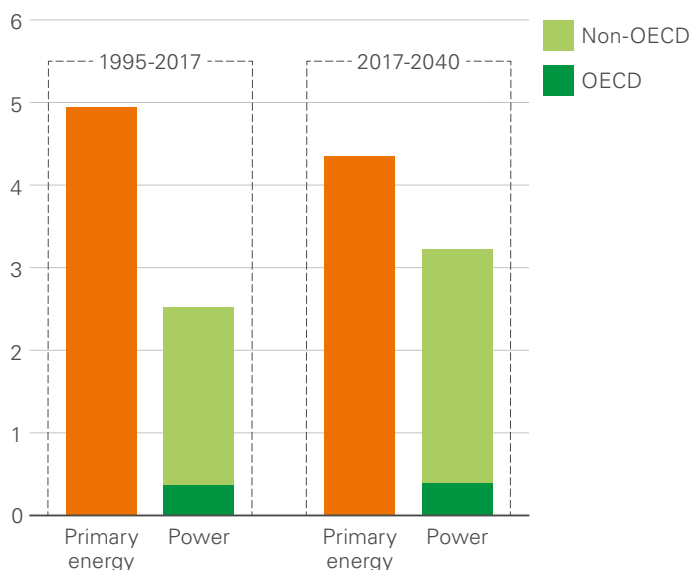
Key points

- ▶ As a result of these measures, CO₂ emissions from transport in the LCT scenario fall by 2% (0.2 Gt) from 2017 levels, compared with an increase of 13% (1.1 Gt) in the ET scenario.
- ▶ Compared with the ET scenario, the majority of the reduction in emissions stems from road transport, particularly via fuel switching. This reflects the importance of road transportation relative to marine and aviation; and the greater scope to electrify different aspects of road use. Increased electrification accounts for around a half of the reduction in emissions relative to the ET scenario by 2040.
- ▶ Compared to the current levels of emissions, improving levels of efficiency within transport mean that the rapid growth in the demand for transport services over the Outlook can be met with almost no increase in energy consumption. The most important driver of these efficiency gains is the significant tightening in vehicle emissions standards, much of which is already reflected in the ET Scenario. The use of car scrappage schemes also helps to improve average car efficiency.
- ▶ The contribution of fuel switching in reducing emissions from current levels is less significant. Increasing electrification accounts for around half of the gains from fuel switching, with the majority of the remainder reflecting greater use of biofuels, which increase by around 4 Mb/d to 6 Mb/d by 2040.

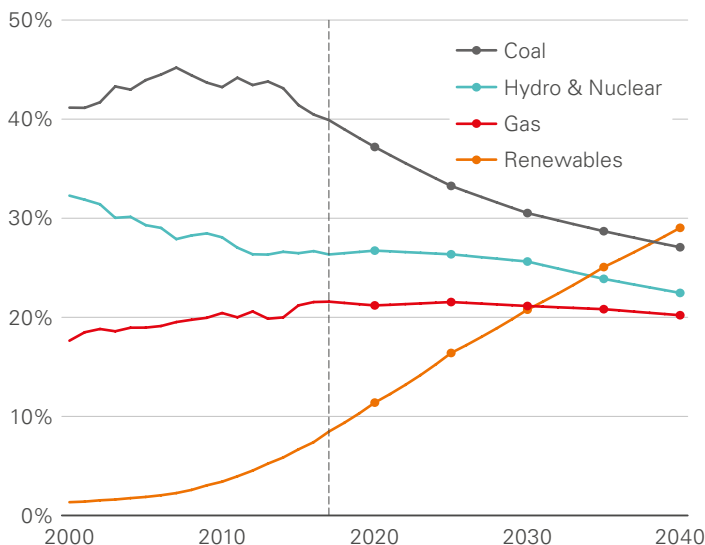
The world continues to electrify, led by developing economies, with renewable energy playing an ever-increasing role

Growth in primary energy and inputs to power

Billion toe



Fuel shares in power



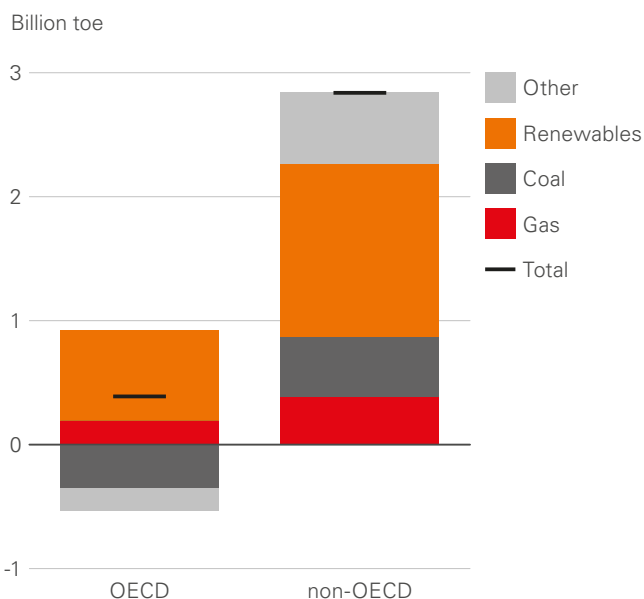
Key points

- ▶ The world continues to electrify, with power consumption growing strongly.
- ▶ In the ET scenario, around three-quarters of the entire growth in primary energy over the Outlook is used for power generation, with around half of all primary energy absorbed by the power sector by 2040.
- ▶ Almost all of the growth in power demand stems from developing economies, led by China and India. Demand growth in the OECD is much smaller, reflecting both slower economic growth and a weaker responsiveness of power demand to economic growth in more mature, developed economies.
- ▶ The mix of fuels in global power generation shifts materially, with renewables gaining share at the expense of coal, nuclear and hydro. The share of natural gas is broadly flat at around 20%.
- ▶ Renewables account for around two-thirds of the increase in power generation, with their share in the global power sector increasing to around 30%. In contrast, the share of coal declines significantly, such that by 2040 it is surpassed by renewables as the primary source of energy in the global power sector.

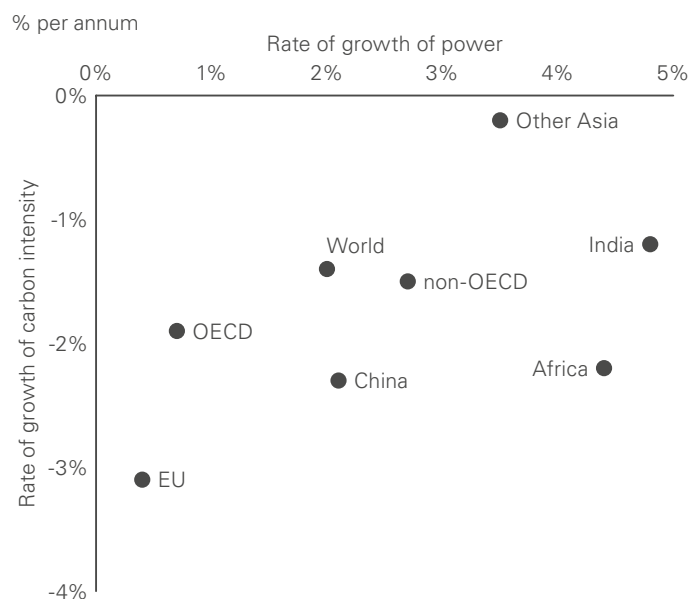
By 2040 renewables overtake coal as the largest source of global power

The strong growth of power demand in developing economies helps renewables penetrate, but also creates demand for coal

Change in primary energy in power 2017-2040



Growth in carbon intensity and power consumption, 2017-2040

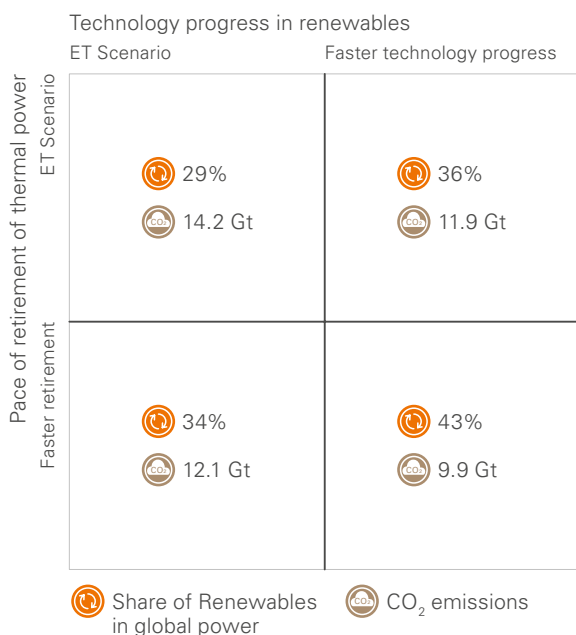


Key points

- ▶ The contrasting trends in power demand in the OECD and developing economies affects the extent to which the power sector can decarbonize.
- ▶ The slower growth of power demand in the OECD slows the speed with which renewables can penetrate since it is hard for a new renewable power station to compete commercially against an existing facility. In the ET scenario, there is some substitution of renewables for coal in the OECD, but the extent of this shift is limited by the pace at which existing power stations are retired.
- ▶ In contrast, the strong growth of power demand in developing economies means there is greater scope for renewables to increase. But in the ET scenario, renewables do not grow sufficiently quickly to meet all of the additional power demand, and as a result coal consumption also increases.
- ▶ In the ET scenario, limits on the pace at which non-fossil fuels can grow results in a trade-off between the growth of power and the pace of decarbonization. Some countries and regions, such as China and Africa, are able to grow non-fossil fuels relatively rapidly and so achieve high levels of decarbonization. In contrast, in some other regions, limits on the extent to which non-fossil fuels can be increased commercially, means there is greater reliance on coal, and so less decarbonization.

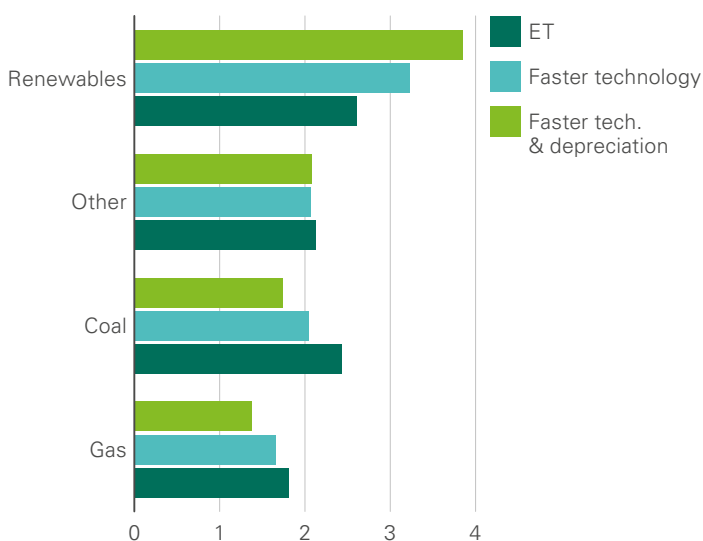
Growth of renewables depends on technical progress and the pace at which existing power stations are retired

Share of renewables in power, and CO₂ emissions



Power mix in 2040

Billion toe



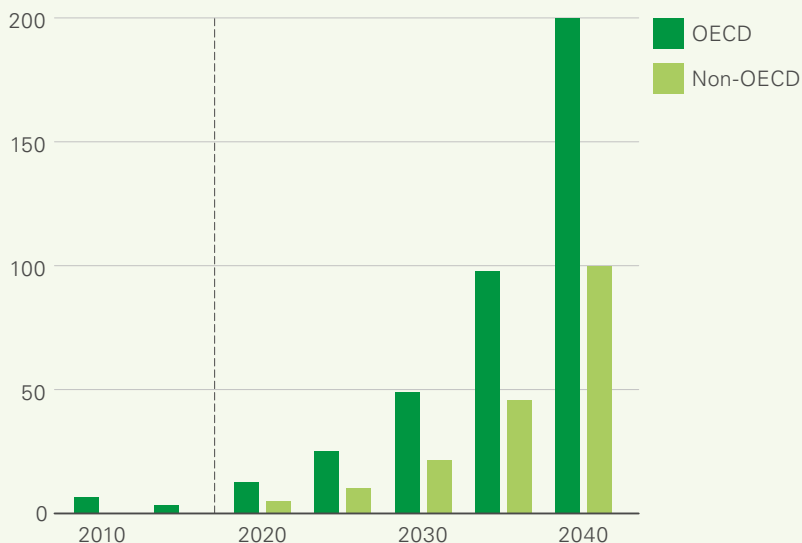
Key points

- ▶ The outlook for renewables is underpinned by continuing gains in technology, but is also affected by a number of other factors.
- ▶ In the ET scenario, the costs of wind and solar power continue to decline significantly, broadly in line with their past learning curves.
- ▶ To give a sense of the importance of technology gains in supporting renewables, if the speed of technological progress was twice as fast as assumed in the ET scenario, other things equal, this would increase the share of renewables in global power by around 7 percentage points by 2040 relative to the ET scenario, and reduce the level of CO₂ emissions by around 2 Gt.
- ▶ The impact of these faster technology gains is partly limited by the speed at which existing power stations are retired, especially in the OECD.
- ▶ If, in addition to faster technological gains, policies or taxes double the rate at which existing thermal power stations are retired relative to the ET scenario, the reduction in emissions is doubled.
- ▶ This suggests that technological progress without other policy intervention is unlikely to be sufficient to decarbonize the power sector over the Outlook. The 'Lower-carbon power' scenario described on pp 58-61 considers a package of policy measures aimed at substantially decarbonizing the global power sector.

Alternative scenario: Lower-carbon power

Alternative scenario: a lower-carbon power sector is driven by higher carbon prices and direct policy measures

Carbon prices

Real \$/t of CO₂

Other policy measures

Regulation:

- ▶ Conventional coal-based generation in OECD banned from 2030
- ▶ Worldwide ban from 2030 on new conventional coal-based generation
- ▶ Support for stronger deployment of nuclear and hydro power

Technology:

Higher R&D spending doubling pace of technological progress in renewables

CCUS:

Incentivise investment in CCUS for gas and coal

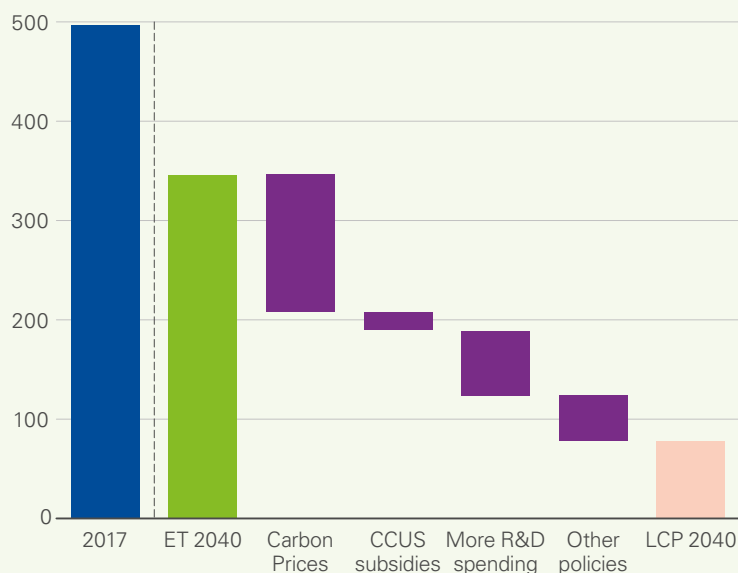
Key points

- ▶ The extent to which the global power sector decarbonizes over the next 20 years has an important bearing on the speed of transition to a lower-carbon energy system.
- ▶ In the ET scenario, the carbon intensity of the power sector declines by around 30% by 2040. The alternative 'Lower-carbon power' (LCP) scenario considers a more pronounced decarbonization of the power sector.
- ▶ This is achieved via a combination of policies. Most importantly, carbon prices are increased to \$200 per tonne of CO₂ in the OECD by 2040 and \$100 in the non-OECD – compared with \$35-50 in OECD and China (and lower elsewhere) in the ET scenario.
- ▶ Carbon prices in the LCP scenario are raised only gradually to avoid premature scrapping of productive assets. To help support carbon prices, especially as their impact is building, a number of additional policy measures are taken:
 - ▶ conventional coal-fired power stations in OECD banned from 2030; worldwide ban from 2030 on new investment in non-CCUS coal stations; support for stronger deployment of nuclear and hydro power;
 - ▶ support for higher R&D investment, which is assumed to double the pace of technological progress;
 - ▶ incentives for investment in carbon capture, use and storage (CCUS) in gas and coal-fired power stations.

Alternative scenario: Lower-carbon power

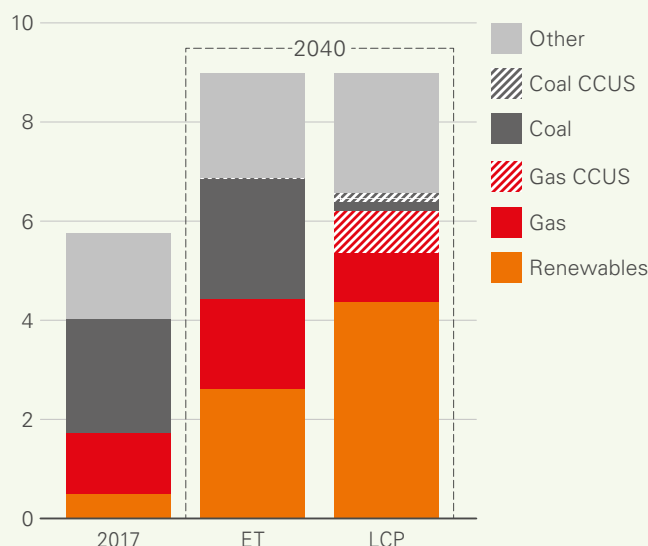
The carbon intensity of the power sector declines by over 75% led by renewables, greater use of CCUS, and less coal

Carbon intensity in ET and LCP scenarios

g of CO₂ per kWh

Inputs to power by fuel

Billion toe



Key points

Carbon prices account for nearly half the fall in CO₂ emissions

- ▶ The carbon intensity of the global power sector in the LCP scenario declines by over 75% relative to the ET scenario. As a result, total CO₂ emissions in the LCP scenario fall by 25% by 2040, compared with an 7% increase in the ET scenario.
- ▶ The most significant factor underpinning this decarbonization is the higher carbon price, which accounts for almost half of the carbon reduction. This is supported by the other measures, especially during the first half of the Outlook as carbon prices gradually rise. The limit on the speed with which carbon prices can be increased without leading to scrapping of productive assets implies other policy measures are needed to achieve significant progress over the next 20 years.
- ▶ Renewables more than account for the entire growth of power generation in the LCP scenario, with their share of the global power sector increasing to around 50% by 2040.
- ▶ The share of natural gas in power is broadly unchanged from its current level, although by 2040 almost half of all gas-fired generation is supported by CCUS. Gas with CCUS is more competitive than coal with CCUS due to the greater carbon content in coal. In total, CCUS captures 2.8 Gt of CO₂ emissions by 2040 in the LCP scenario.
- ▶ Coal is the main loser in the LCP scenario, with its share declining from around 40% in 2017 to less than 5% by 2040.

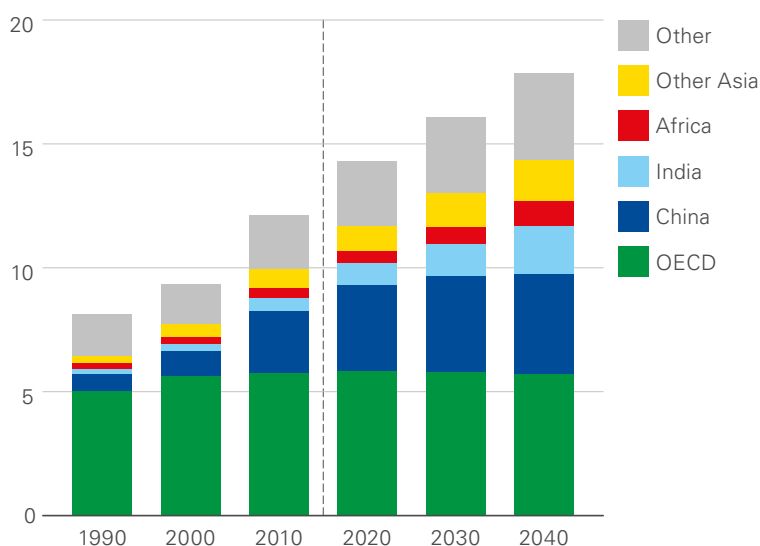
Regions

Regional consumption
Fuel mix across key countries and regions
Regional production
Global energy trade
Alternative scenario: Less globalization

A transition is underway in the global pattern of demand, with the dominance of the developing world increasing

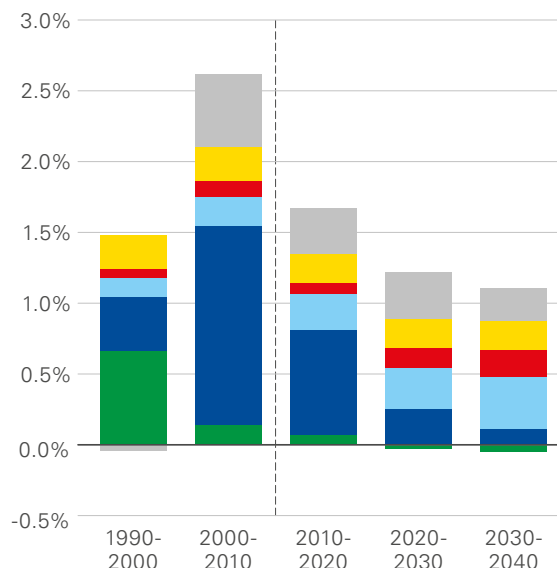
Primary energy consumption by region

Billion toe



Primary energy growth and regional contributions

% per annum



Key points

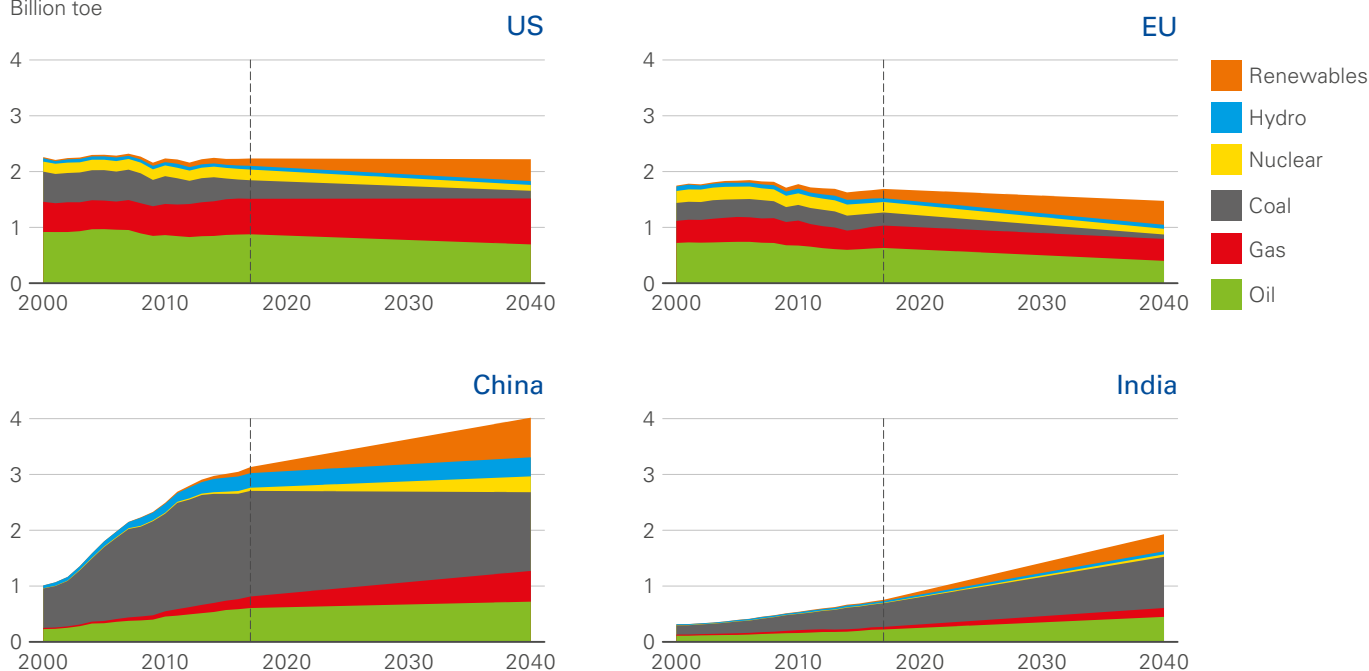
By mid-2020s India is the world's largest growth market

- ▶ There is an energy transition underway in the global pattern of energy demand, with the developing world increasing its role as the main market for energy consumption.
- ▶ In 1990, the OECD accounted for almost two-thirds of energy demand, with the developing world just one-third. In the ET scenario, that position is almost exactly reversed by 2040, with the non-OECD accounting for over two-thirds of demand.
- ▶ Much of the increase in energy demand is concentrated in developing Asia (India, China, and Other Asia), where rising prosperity and improving living standards support increasing energy consumption per head. See pp 22-25 for a discussion of the importance of providing 'more energy'.
- ▶ China's transition to a more sustainable pattern of economic growth means that by the mid-2020s India surpasses China as the world's largest growth market, accounting for over a quarter of the growth in global energy demand over the Outlook. Even so, China remains the largest market for energy: roughly double the size of India in 2040.
- ▶ Africa's energy consumption remains small relative to its size: in 2040 Africa accounts for almost a quarter of the world's population, but only 6% of energy demand.

Differences in the fuel mix across regions have an important influence on the energy transition

Primary energy consumption by region and fuel

Billion toe



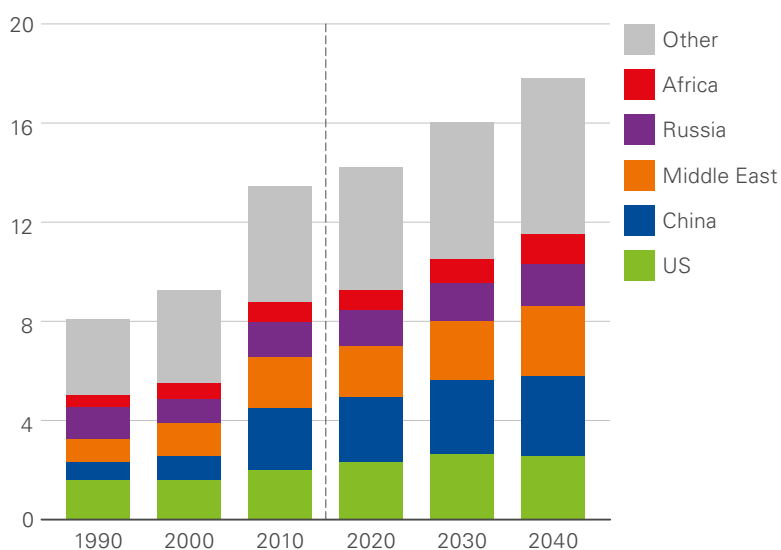
Key points

- ▶ Differences in the fuel mix across regions, and the extent to which that mix changes over the Outlook, have an important bearing on the energy transition.
- ▶ The two countries accounting for the fastest growth in energy demand – India and China – both start with relatively coal-intensive fuel mixes.
- ▶ In the ET scenario, China's coal share declines sharply over the Outlook – falling from 60% in 2017 to around 35% in 2040 – largely offset by increasing shares of renewables and natural gas. Indeed, in China, the growth of non-fossil fuels (renewables plus nuclear and hydro power) more than matches the entire growth in Chinese energy demand over the Outlook.
- ▶ In contrast, the share of coal within India declines only modestly, driven by increasing coal consumption within the Indian power sector (pp 102-103).
- ▶ The US and EU both start the Outlook with relatively diverse fuel mixes and, over the Outlook, share similar trajectories of declining shares of coal and oil offset by increasing use of renewables and, in the US, natural gas.

The global pattern of energy production is shifting with strong growth in US supply and slowing growth in China

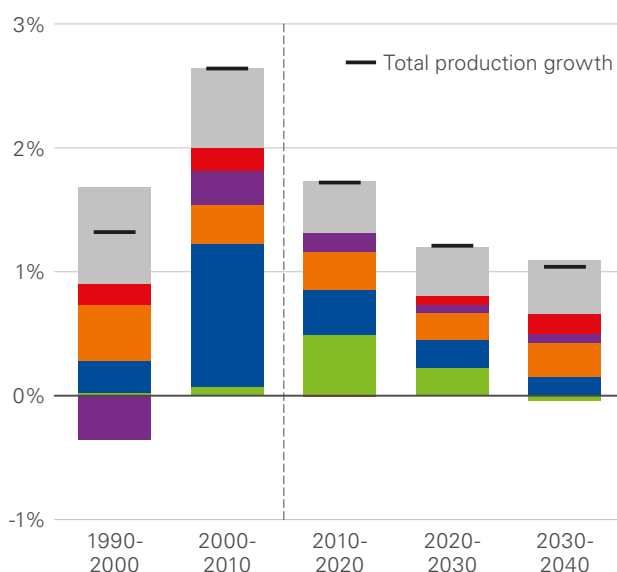
Primary energy supply by region

Billion toe



Primary energy supply growth and regional contributions

% per annum

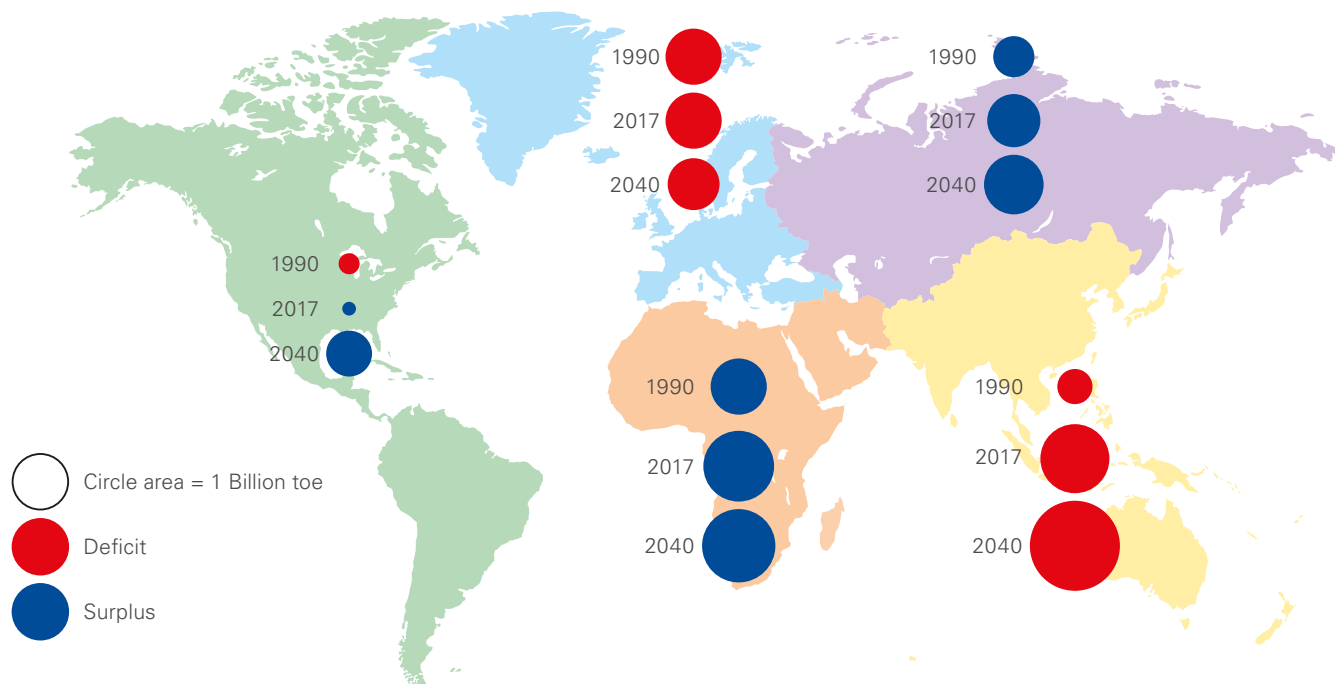


Key points

- ▶ The global pattern of energy production is also shifting, with strong growth in US energy production and a slowing in the expansion of Chinese energy supplies.
- ▶ US energy production increases markedly in the ET scenario, driven by increases in oil, gas, and renewables. The US is the largest contributor to energy production growth until the mid-2020s; after which growth slows as tight oil production peaks and gradually declines.
- ▶ The growth of energy production in China slows markedly relative to the past 20 years as China adjusts to a more sustainable pattern of economic growth. Despite this slowing, China is the world's largest source of growth in energy supplies over the Outlook, driven by rapid growth in renewables and nuclear power (pp 104-109).
- ▶ The Middle East maintains its role as a key source of energy, supported by the growth of OPEC oil production in the second half of the Outlook (pp 86-87), together with an expansion in gas production in Qatar and Iran (pp 94-95).
- ▶ Russia's share of global energy production declines slightly over the Outlook, largely reflecting an edging down in its share of global gas production. Even so, Russia remains the world's largest exporter of oil and gas. The changing global pattern of energy trade and imbalances is considered on pp 70-71.

The contrasting patterns in energy demand and production lead to significant shifts in global energy trade flows

Energy balance of traded fuels (oil, gas, coal)



Key points

- ▶ The differing regional trends in energy consumption and production lead to significant shifts in the pattern of energy trade across the globe.
- ▶ The ET scenario points to sharply contrasting patterns in the energy balances (consumption minus production) of the Americas and Asia, which were both small net importers of energy 20 years or so ago.
- ▶ The rapid growth of US tight oil and shale gas leads to a significant increase in net energy exports from the Americas, such that by 2040 the Americas are a material source of energy exports to the rest of the world.
- ▶ In contrast, the rapid growth of energy demand in Asia, led by India, China, and Other Asia, reinforces Asia's position as the largest market for energy imports. The impact that trade disputes and increasing concerns about energy security could have on the pattern of energy flows is considered in the alternative 'Less globalization' scenario on pp 72-75.
- ▶ The slow growth of energy consumption relative to production over the Outlook allows Russia and other CIS countries to increase their share of world energy exports. In contrast, the net energy exports of the Middle East and Africa are relatively unchanged.

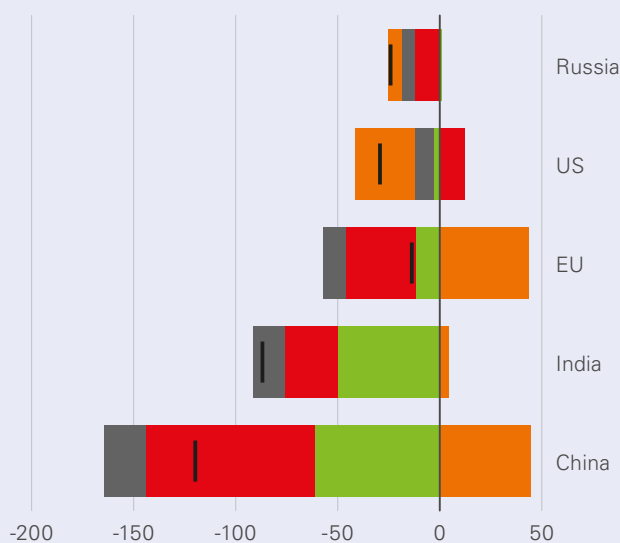
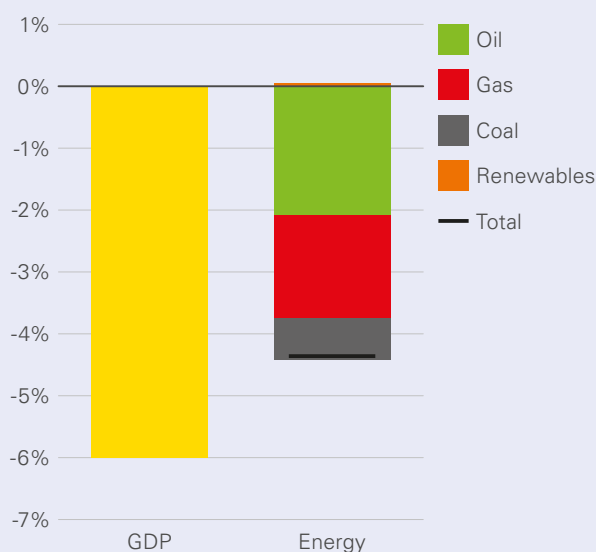
The US becomes a major energy exporter over the Outlook

Alternative scenario: Less globalization

Alternative scenario: an escalation of recent trade disputes could reduce energy demand and energy trade

Difference relative to ET scenario in 2040:
Global GDP and energyDifference relative to ET scenario in 2040:
Regional fuel demand

Mtoe



Key points

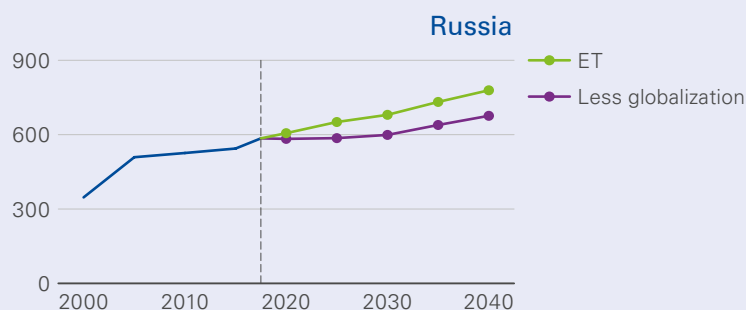
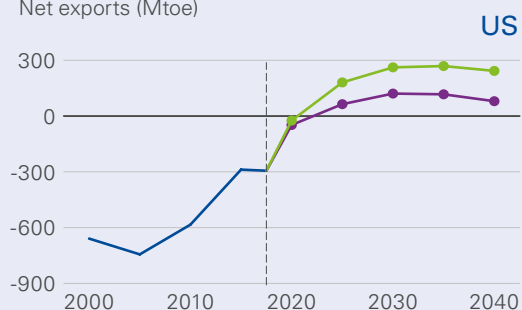
- ▶ International trade has an important influence on the global energy system: it underpins economic growth and allows countries to diversify their sources of energy.
- ▶ If the recent trade disputes escalate they could have a significant impact on the energy outlook. The alternative 'Less globalization' scenario considers a case in which trade disputes increase and have a persistent impact on the energy system. In particular:
 - ▶ the reduced openness of the global economy is assumed to lead to a slight reduction (0.3 percentage points p.a.) in trend global GDP growth;
 - ▶ increased concerns about energy security lead countries to attach a small risk premium (10%) on imported sources of energy.
- ▶ Slower trend GDP growth reduces the level of world GDP by 6% and energy demand by 4% in 2040 relative to the ET scenario, with those falls concentrated in countries and regions most exposed to foreign trade. The risk premia on imported energy means the fall in energy consumed is concentrated in traded fuels (oil, gas and coal), with renewable energy increasing slightly.
- ▶ This general pattern is also evident in individual countries: lower energy demand and a shift in the fuel mix towards domestically-produced sources of energy.

Alternative scenario: Less globalization

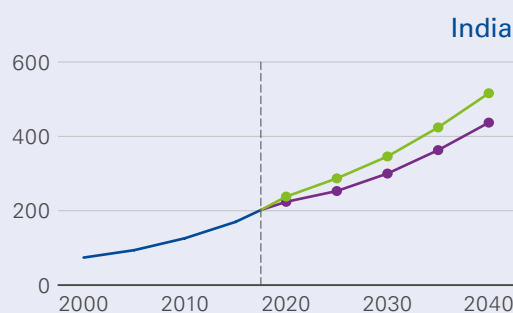
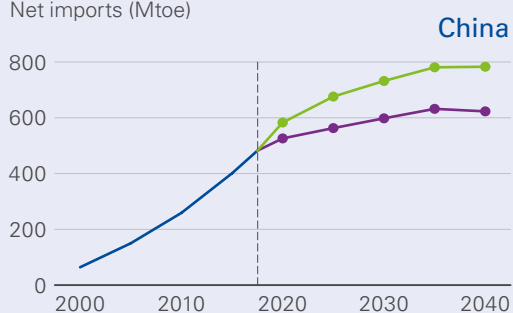
Lower energy demand and reduced trade flows could significantly affect oil and gas imports and exports

Net exporting/importing (oil & gas)

Net exports (Mtoe)



Net imports (Mtoe)



Key points

- ▶ The lower level of energy demand, together with the increased concerns about energy security, leads to a sharp reduction in energy trade, as overall demand falls and countries revert to domestically produced sources of energy.
- ▶ This has a material impact on the largest exporters of oil and gas, such as Russia and the US. The growth of Russia's oil and gas net exports by 2040 in the 'Less globalization' scenario is more than 50% lower than in the ET scenario.
- ▶ The impact on the growth of US net oil and gas exports is even more pronounced as the US consumes more of its gas domestically, crowding out the growth of renewable energy. By 2040, US oil and gas exports in the 'Less globalization' scenario are around two-thirds lower than in the ET scenario.
- ▶ In terms of imports, the energy deficits of the major importers of oil and gas, such as China and India, are smaller than in the ET scenario. For example, China's imports of oil and gas in the 'Less globalization' scenario are respectively 12% and 40% lower than in the ET scenario.
- ▶ This reduction in imported energy stems from both the lower overall level of energy consumption and the shift away from oil and gas towards domestically produced renewables.

Demand and supply of fuels

Overview

Oil

Alternative scenario: Greater reform

Natural gas

Coal

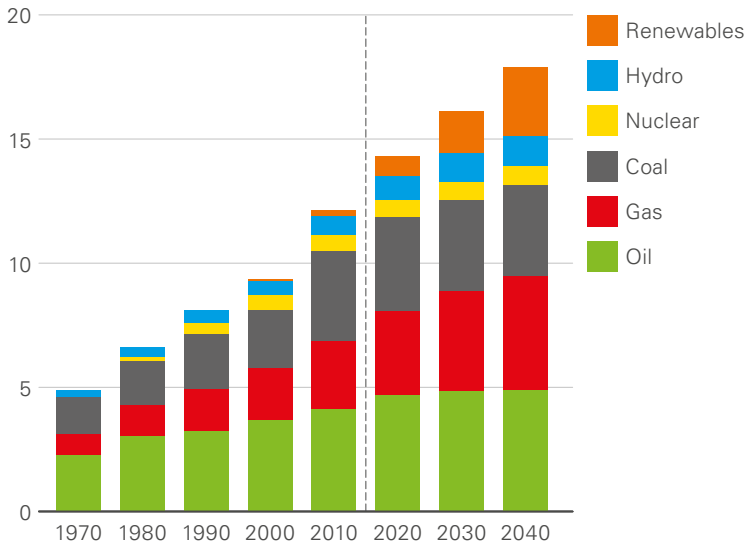
Renewables

Nuclear and hydro

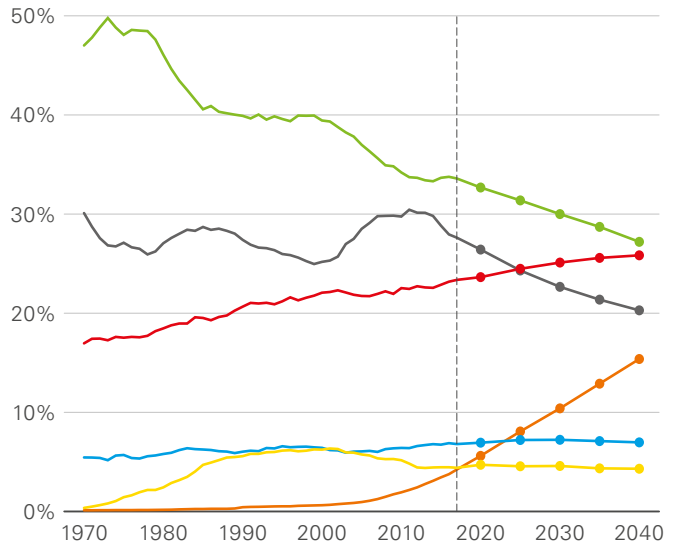
The transition to a lower-carbon fuel mix continues, led by renewables and natural gas

Primary energy consumption by fuel

Billion toe



Shares of primary energy



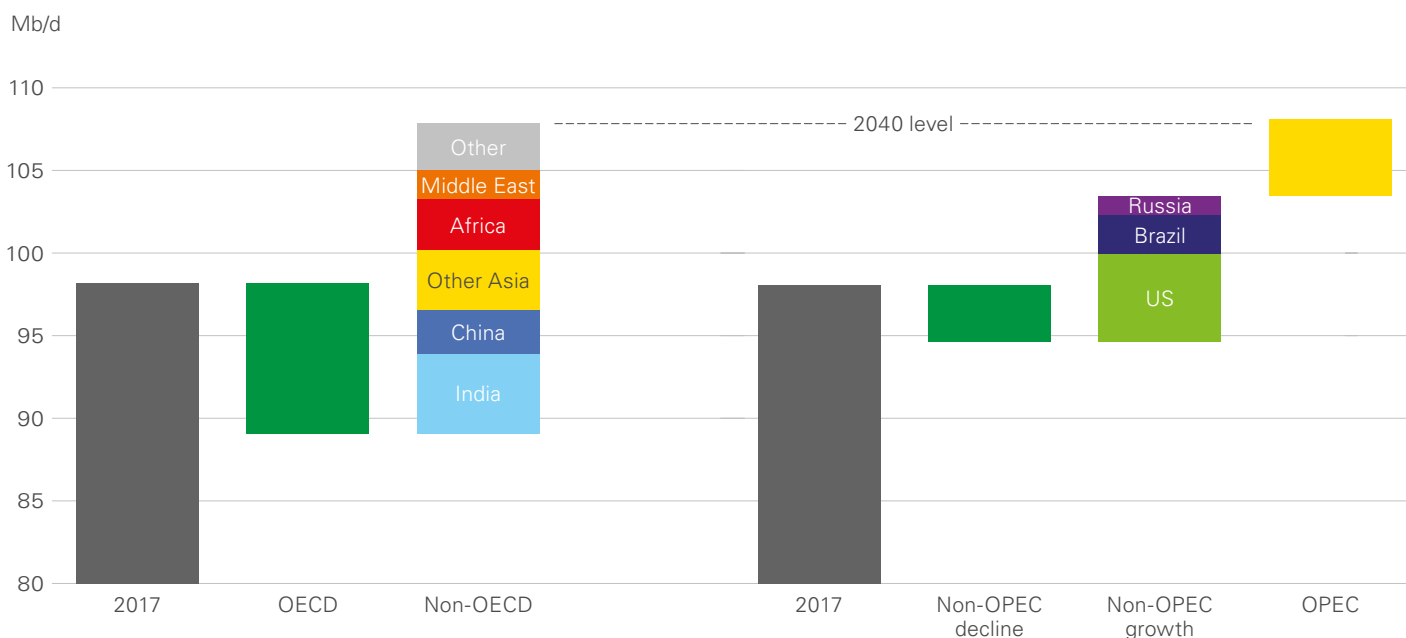
Key points

Renewables and natural gas account for 85% of energy growth

- ▶ The transition to a lower-carbon energy system continues, with renewable energy and natural gas gaining in importance relative to oil and coal.
- ▶ In the ET scenario, renewables and natural gas account for almost 85% of the growth in primary energy, with their importance increasing relative to all other sources of energy.
- ▶ Renewable energy (7.1% p.a.) is the fastest growing source of energy, contributing half of the growth in global energy, with its share in primary energy increasing from 4% today to around 15% by 2040.
- ▶ Natural gas (1.7% p.a.), grows much faster than either oil or coal, overtaking coal to be the second largest source of global energy and converging on oil by the end of the Outlook.
- ▶ Oil (0.3% p.a.) increases during the first half of the Outlook, although much slower than in the past, before plateauing in the 2030s.
- ▶ Coal consumption (-0.1% p.a.) is broadly flat over the Outlook, with its importance in the global energy system declining to its lowest level since before the industrial revolution.

Growing demand for liquid fuels in emerging economies is met by increased supplies from low-cost producers

Demand



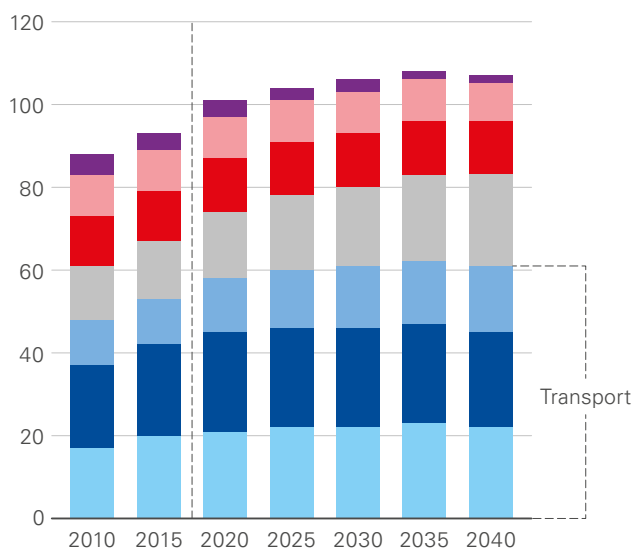
Key points

- ▶ The global market for liquid fuels is set to continue to expand for a period, with growing demand from developing economies met by increased supplies mainly from the US and OPEC.
- ▶ In the ET scenario, global demand for liquid fuels – crude and condensates, natural gas liquids (NGLs), and other liquids – increases by 10 Mb/d, plateauing around 108 Mb/d in the 2030s.
- ▶ All of the demand growth comes from developing economies, driven by the burgeoning middle class in developing Asian economies. Consumption of liquid fuels within the OECD resumes its declining trend.
- ▶ The growth in demand is initially met from non-OPEC producers, led by US tight oil. But as US tight oil production declines in the final decade of the Outlook, OPEC becomes the main source of incremental supply. OPEC output increases by 4 Mb/d over the Outlook, with all of this growth concentrated in the 2030s.
- ▶ Non-OPEC supply grows by 6 Mb/d, led by the US (5 Mb/d), Brazil (2 Mb/d) and Russia (1 Mb/d) offset by declines in higher-cost, mature basins.

Consumption of liquid fuels grows over the next decade, before broadly plateauing in the 2030s

Liquids demand

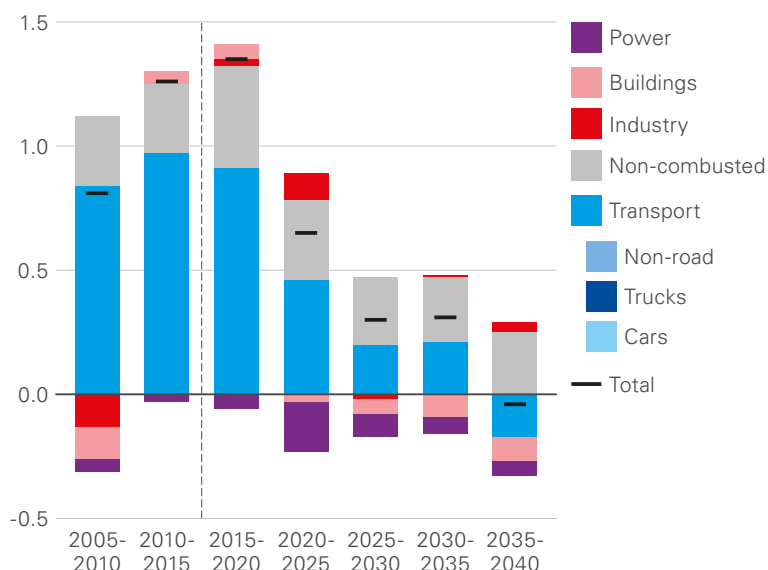
Mb/d



Cars include 2- and 3-wheelers. Trucks includes most SUVs in North America. Non-road includes aviation, marine and rail

Liquids demand growth

Mb/d, average annual growth

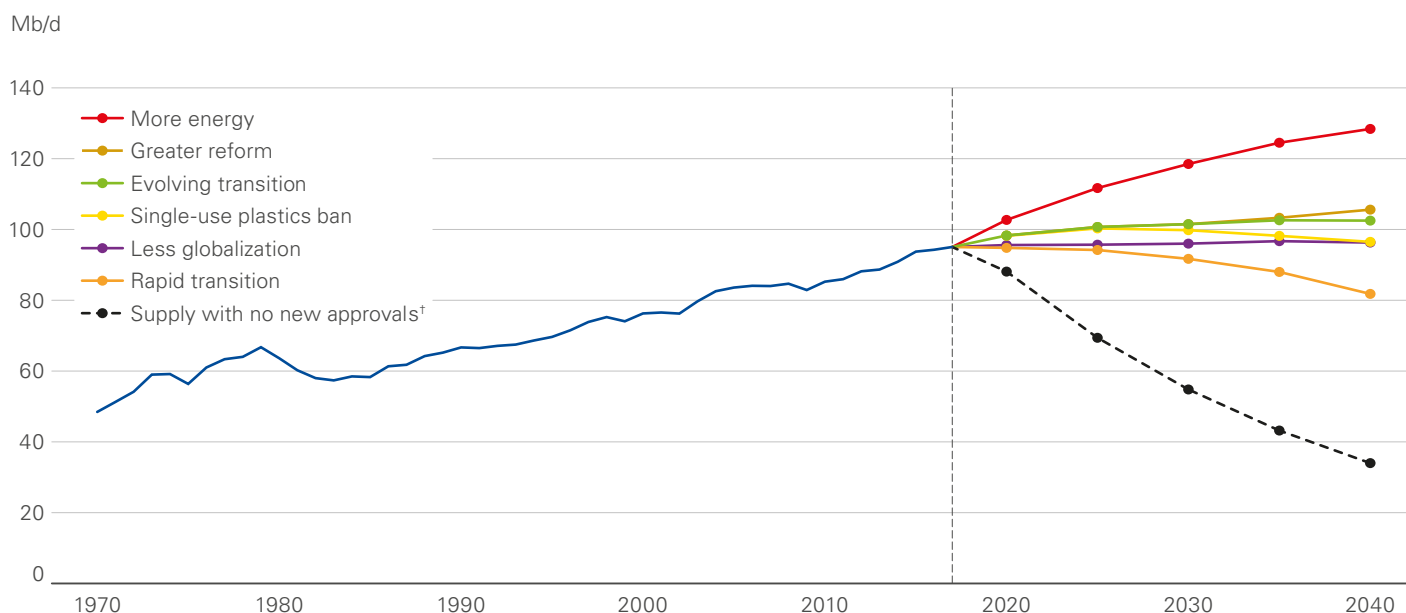


Key points

- Demand for liquid fuels looks set to expand for a period before gradually plateauing as efficiency improvements in the transport sector accelerate.
- In the ET scenario, consumption of liquid fuels increases by 10 Mb/d (from 98 Mb/d to 108 Mb/d), with the majority of that growth happening over the next ten years or so.
- The demand for liquid fuels continues to be dominated by the transport sector, with its share of liquids consumption remaining around 55%. Transport demand for liquid fuels increases from 56 Mb/d to 61 Mb/d by 2040, with this expansion split between road (2 Mb/d) (divided broadly equally between cars, trucks, and 2/3 wheelers) and aviation/marine (3 Mb/d).
- But the impetus from transport demand fades over the Outlook as the pace of vehicle efficiency improvements quicken and alternative sources of energy penetrate the transport system (pp 42-45).
- In contrast, efficiency gains when using oil for non-combusted uses, especially as a feedstock in petrochemicals, are more limited. As a result, the non-combusted use of oil takes over as the largest source of demand growth over the Outlook, increasing by 7 Mb/d to 22 Mb/d by 2040 (pp 32-33).

The outlook for oil demand is uncertain but looks set to play a major role in global energy out to 2040

Demand and supply of oil*



* Excluding GTLs and CTLs

† Based on IEA's WEO 2018 assumption if future investment is limited to developing existing fields and there was no investment in new production areas

Key points

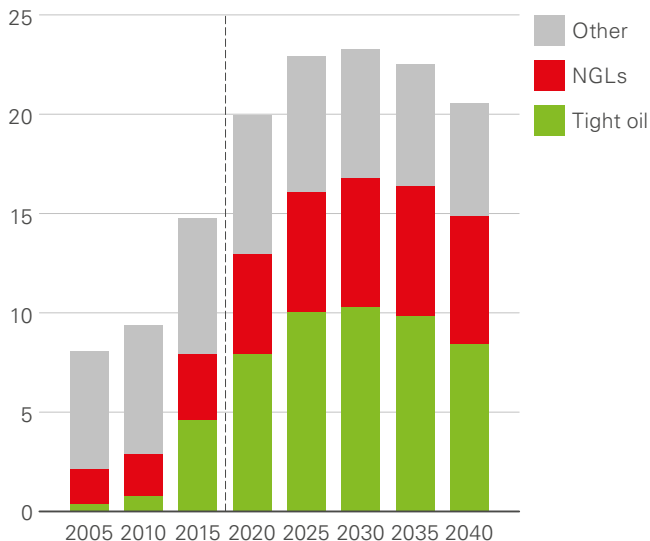
- ▶ Although the precise outlook is uncertain, the world looks set to consume significant amounts of oil (crude plus NGLs) for several decades, requiring substantial investment.
- ▶ This year's *Energy Outlook* considers a range of scenarios for oil demand, with the timing of the peak in demand varying from the next few years to beyond 2040. Despite these differences, the scenarios share two common features.
- ▶ First, all the scenarios suggest that oil will continue to play a significant role in the global energy system in 2040, with the level of oil demand in 2040 ranging from around 80 Mb/d to 130 Mb/d.
- ▶ Second, significant levels of investment are required for there to be sufficient supplies of oil to meet demand in 2040. If future investment was limited to developing existing fields and there was no investment in new production areas, global production would decline at an average rate of around 4.5% p.a. (based on IEA's estimates), implying global oil supply would be only around 35 Mb/d in 2040.
- ▶ Closing the gap between this supply profile and any of the demand scenarios in the Outlook would require many trillions of dollars of investment over the next 20 years.

In all scenarios, trillions of dollars of investment in oil is needed

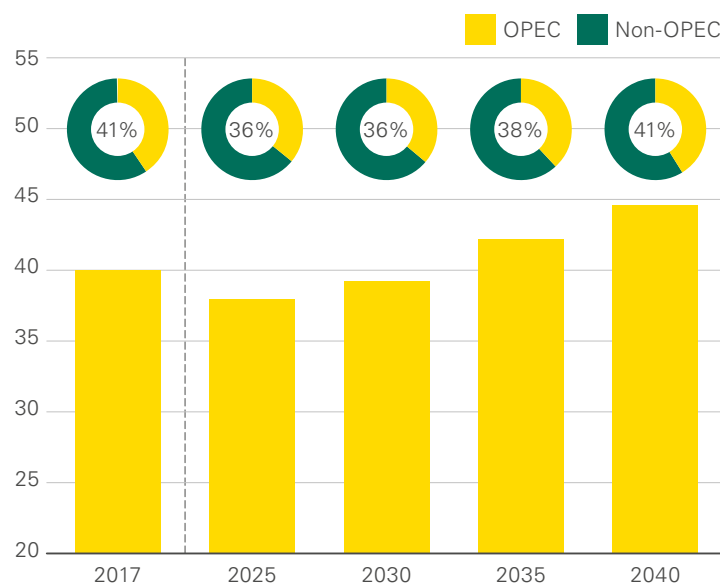
Growth in liquids supply is initially dominated by US tight oil, with OPEC production increasing only as US tight oil declines

US liquids supply

Mb/d



OPEC Supply and market share



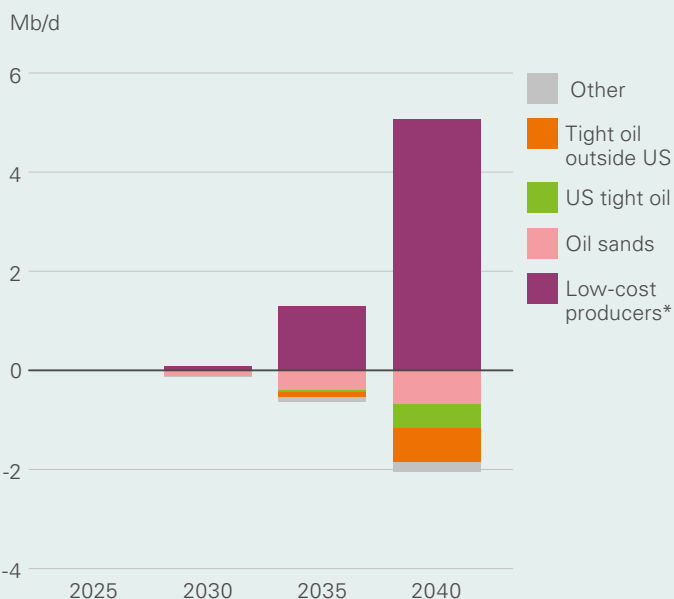
Pie charts show OPEC and non-OPEC shares

Key points

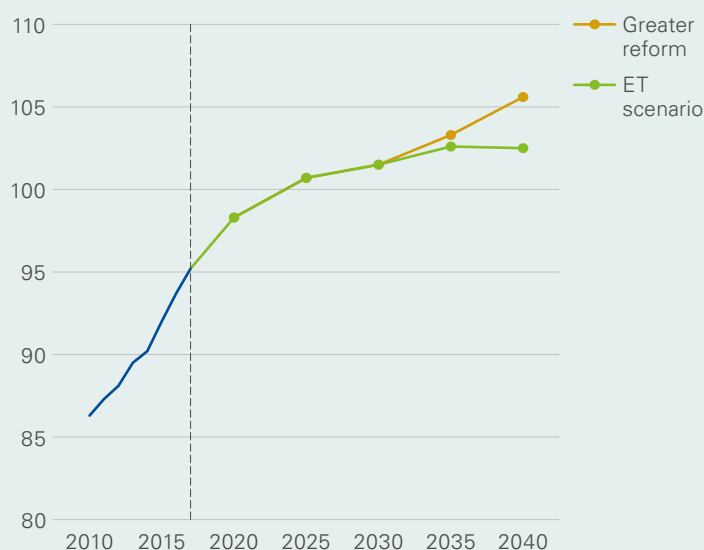
- ▶ Growth in global liquids production is dominated in the first part of the Outlook by US tight oil, with OPEC production gaining in importance further out.
- ▶ In the ET scenario, total US liquids production accounts for the vast majority of the increase in global supplies out to 2030, driven by US tight oil and NGLs. US tight oil increases by almost 6 Mb/d in the next 10 years, peaking at close to 10.5 Mb/d in the late 2020s, before falling back to around 8.5 Mb/d by 2040. The strong growth in US tight oil reinforces the US's position as the world's largest producer of liquid fuels.
- ▶ As US tight oil declines, this space is filled by OPEC production, which more than accounts for the increase in liquid supplies in the final decade of the Outlook.
- ▶ The increase in OPEC production is aided by OPEC members responding to the increasing abundance of global oil resources by reforming their economies and reducing their dependency on oil, allowing them gradually to adopt a more competitive strategy of increasing their market share.
- ▶ The speed and extent of this reform is a key uncertainty affecting the outlook for global oil markets (see pp 88-89).
- ▶ The stalling in OPEC production during the first part of the Outlook causes OPEC's share of global liquids production to fall to its lowest level since the late 1980s before recovering towards the end of the Outlook.

Alternative scenario: Greater reform

Alternative scenario: the abundance of global oil resources could lead to a more competitive market, boosting demand

Change in oil supply
(Greater reform vs. ET scenario)

Oil demand†

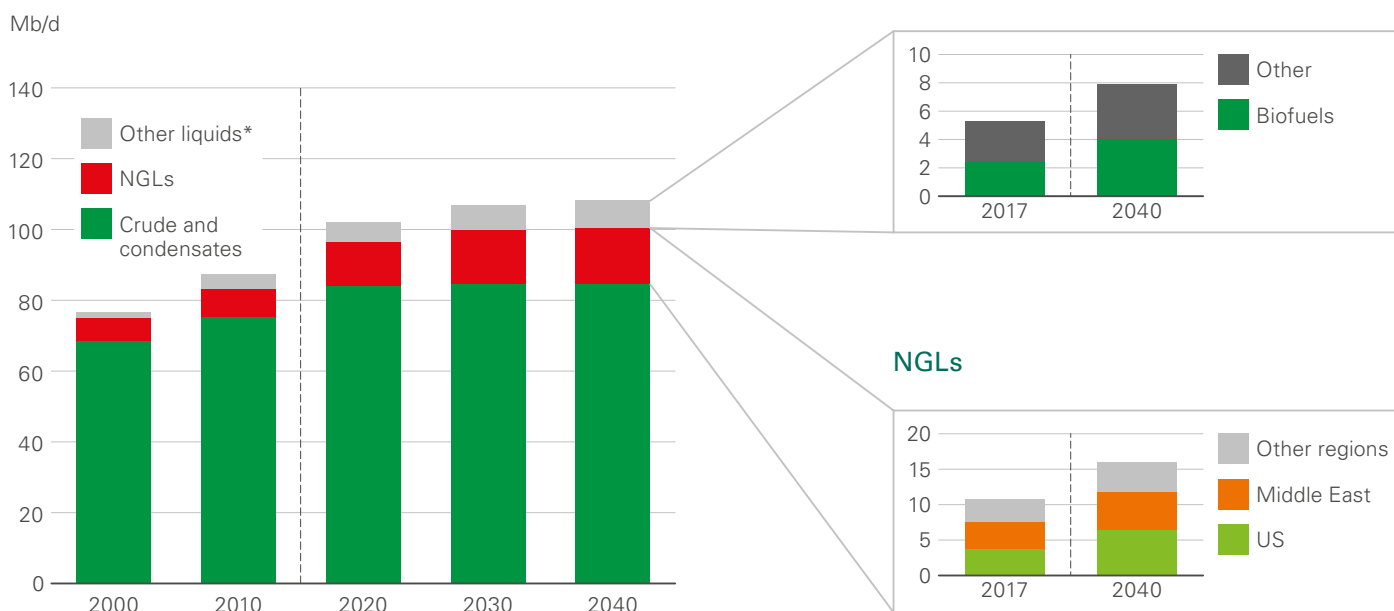


Key points

- ▶ The abundance of oil resources, and risk that large quantities of recoverable oil will never be extracted, may prompt low-cost producers to use their comparative advantage to expand their market share in order to help ensure their resources are produced.
- ▶ The extent to which low-cost producers can sustainably adopt such a 'higher production, lower price' strategy depends on their progress in reforming their economies, reducing their dependence on oil revenues.
- ▶ In the ET scenario, low-cost producers are assumed to make some progress in the second half of the Outlook, but the structure of their economies still acts as a material constraint on their ability to exploit fully their low-cost barrels.
- ▶ The alternative 'Greater reform' scenario assumes a faster pace of economic reform, allowing low-cost producers to increase their market share. The extent to which low-cost producers can increase their market share depends on: the time needed to increase production capacity; and on the ability of higher-cost producers to compete, by either reducing production costs or varying fiscal terms.
- ▶ The lower price environment associated with this more competitive market structure boosts demand, with the consumption of oil growing throughout the Outlook.

Growth in liquid fuels supplies is driven by NGLs and biofuels, with only limited growth in crude oil production

Global liquids supply



*Other liquids includes biofuels, GTL/CTL and refinery gains

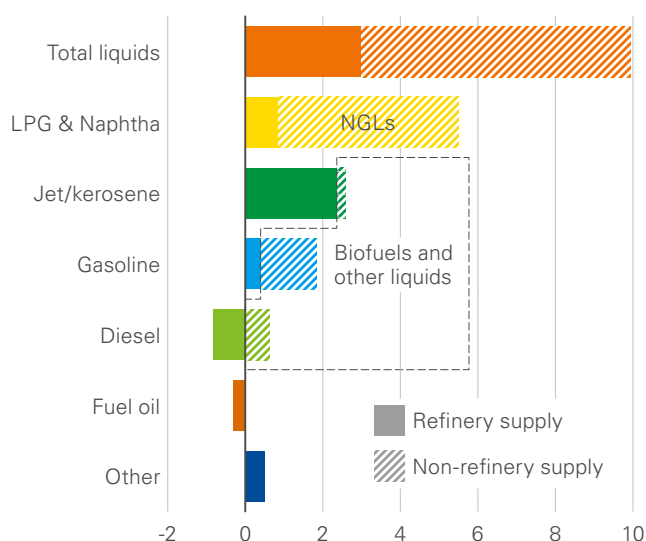
Key points

- ▶ The increase in liquid fuels supplies is set to be dominated by increases in NGLs and biofuels, with only limited growth in crude.
- ▶ In the ET scenario, global liquid fuel supplies increase by 10 Mb/d over the Outlook. Growth of crude and condensates account for less than 3 Mb/d of that increase. The majority of the growth stems from increased production of NGLs (5 Mb/d) and 'other' liquid fuels (3 Mb/d), particularly biofuels.
- ▶ The increase in NGLs is driven mainly by the US (3 Mb/d) and the Middle East (2 Mb/d). NGLs supplies largely stem from gas production, except in the US where NGLs are also linked to tight oil production. The increase in NGLs over the Outlook is supported by the strong growth in the non-combusted use of liquid fuels (pp 32-33).
- ▶ 'Other' liquid fuels are dominated by biofuels, which increase from 2 Mb/d to 4 Mb/d by 2040, with the majority of this production concentrated in the US and Brazil.

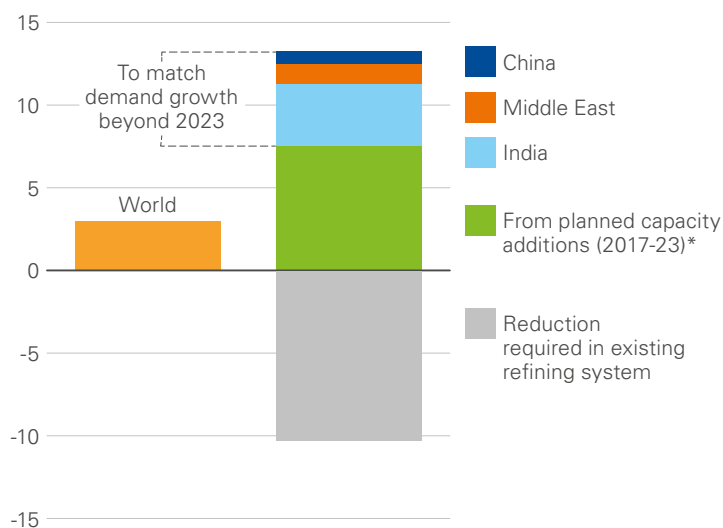
Growth in liquids demand is largely met by non-refined liquids, limiting the growth in refining throughput

Demand and supply growth by product, 2017-2040

Mb/d



Refining throughput growth, 2017-2040



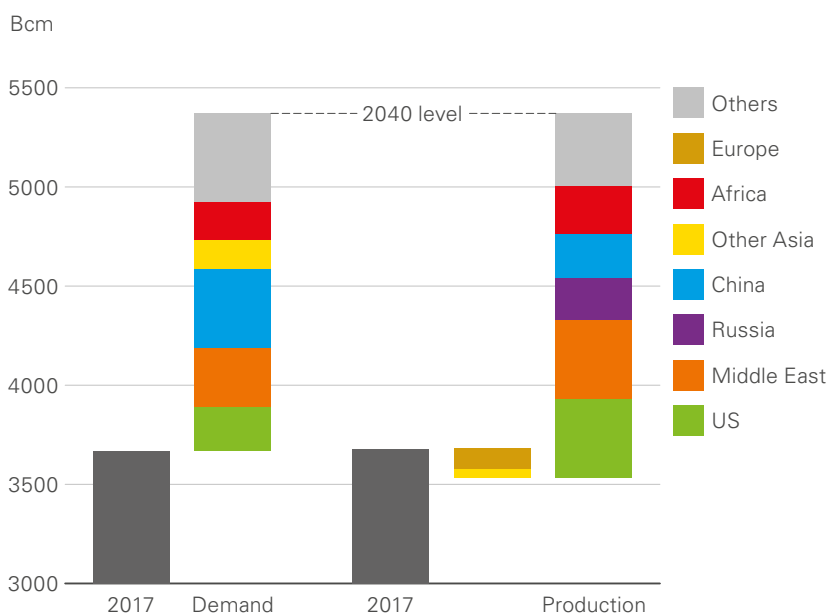
*Assumes planned capacity runs at 85% utilization rate

Key points

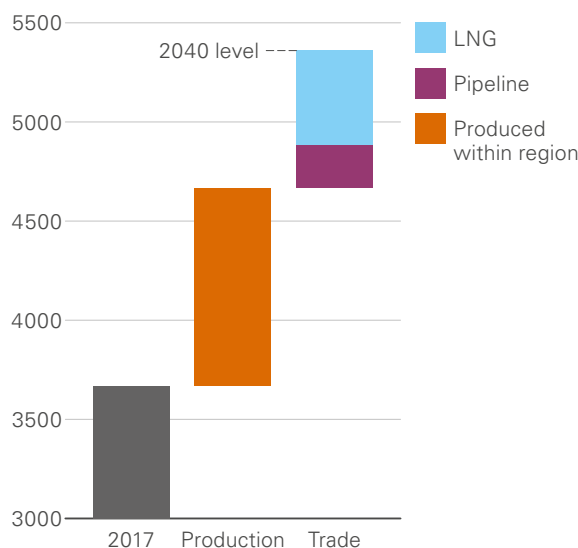
- ▶ The growth in liquids demand is largely met by non-refined supply, dampening the increase in refinery runs.
- ▶ In the ET scenario, the growth in liquids demand is dominated by LPG and naphtha – supported by growing use in petrochemicals – and to a lesser extent gasoline and jet fuel. The increase in LPG, naphtha and gasoline is met largely by NGLs and bioethanol; with only the growth in kerosene sourced mainly from refineries.
- ▶ The strong growth in non-refined liquids weighs on refining throughput, which plateaus in the mid 2020s and is only 3 Mb/d higher by 2040. This compares with around 9 Mb/d of new refining capacity planned or under construction between 2017 and 2023.
- ▶ In addition, many emerging economies in the past – including China, India and the Middle East – have typically built refining capacity to meet (or exceed) their own demand growth. If those regions were to continue that practice, this would imply that throughput outside of these countries would need to fall by around 10 Mb/d from today's levels. This would likely result in substantial refinery closures in mature markets such as Europe, OECD Asia and parts of North America.

Natural gas grows strongly, with broad-based demand low-cost supplies and increasing global availability

Gas demand and production, 2017-2040



Gas trade, 2017-2040



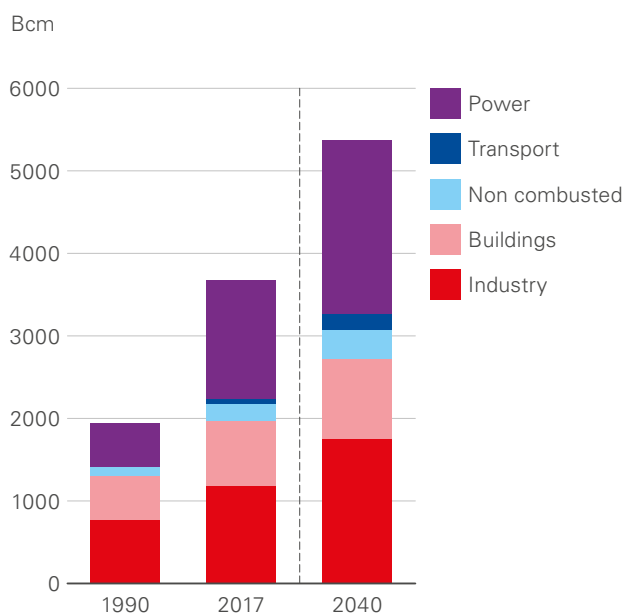
Key points

Gas demand grows in almost every country and region considered

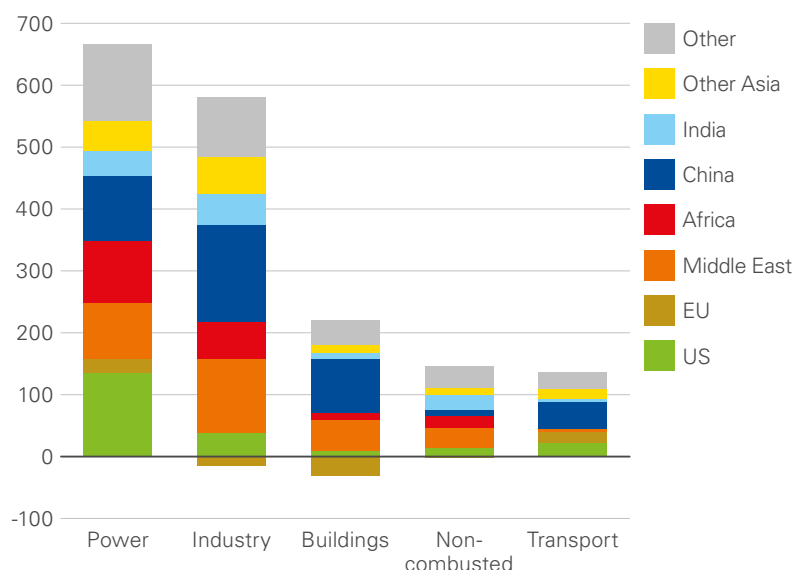
- ▶ Natural gas grows strongly, supported by broad-based demand, plentiful low-cost supplies, and the increasing availability of gas globally, aided by the growing supplies of liquefied natural gas (LNG).
- ▶ In the ET scenario, natural gas grows at an average rate of 1.7% p.a. - increasing nearly 50% by 2040 - the only source of energy, along with renewables, whose share in primary energy increases over the Outlook.
- ▶ Growth in gas demand is widespread, increasing in almost every country and region considered in the Outlook. The increase is driven in broadly equal amounts by use in power and industry. Transport records the fastest growth, albeit with small volumes.
- ▶ Global gas production is led by the US and Middle East (Qatar and Iran) – who together account for almost 50% of the growth in gas production over the Outlook – supported by strong increases in output in both China and Russia.
- ▶ The importance of gas trade continues to grow over the Outlook, driven by robust expansion of LNG supplies which account for more than 15% of total gas demand in 2040, overtaking inter-regional pipeline shipments in the late 2020s.

Growth in gas demand is driven by use in industry and power, with the use of gas varying across countries and regions

Gas consumption: By sector



Gas consumption: Growth by sector and region, 2017-2040



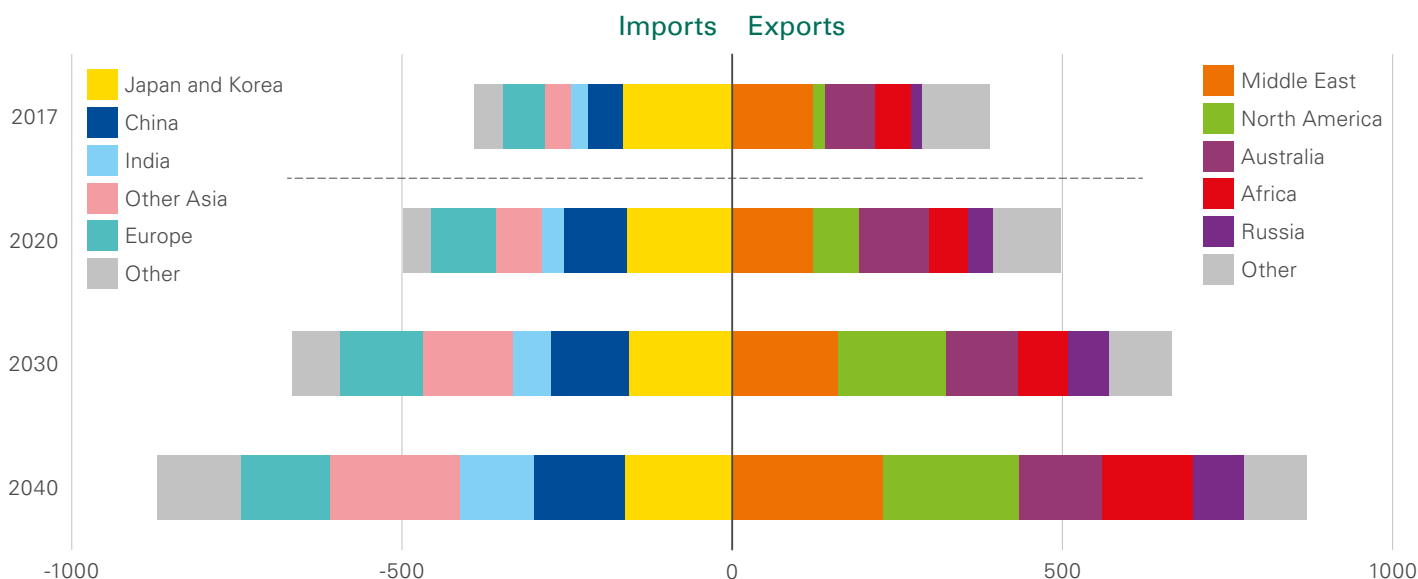
Key points

- ▶ Growth in natural gas demand is led by industry and the power sector.
- ▶ In the ET scenario, the use of gas in industry accelerates over the Outlook, while the growth of gas in the power sector slows.
- ▶ The increased industrial demand for gas over the Outlook is largely driven by developing economies as they continue to industrialize, especially in regions with large gas resources (Middle East, Africa). Coal-to-gas switching, especially in China, also supports gas demand in industry.
- ▶ The additional gas absorbed by the power sector is driven by the overall growth of power demand, with the share of natural gas in the global power sector remaining relatively stable at around 20% (pp 52-53). Among the major gas producers, only North America experiences an increase in the share of gas at the expense of coal.
- ▶ Although the use of gas within transport grows rapidly, it remains small relative to industry and power.
- ▶ The speed and pattern of growth in gas demand, particularly in the non-OECD, is dependent on the pace at which the required supporting infrastructure is built: this is a key source of uncertainty concerning the Outlook for natural gas.

LNG exports increase significantly, led by US and Qatar, fostering a more competitive and globally-integrated market

LNG imports and exports

Bcm



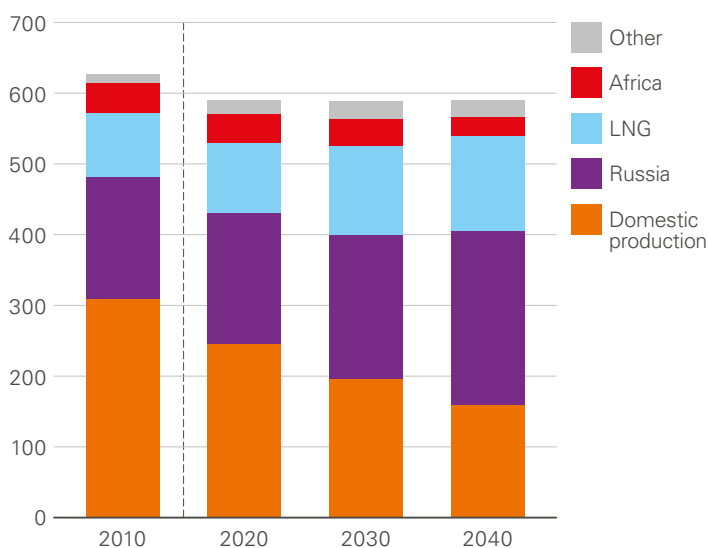
Key points

- ▶ Global LNG volumes are set to expand substantially, leading to a more competitive, globally-integrated gas market.
- ▶ In the ET scenario, LNG trade more than doubles, reaching almost 900 Bcm in 2040 up from around 400 Bcm in 2017.
- ▶ The increase in LNG exports is led by North America, followed by the Middle East, Africa and Russia. As the LNG market matures, the US and Qatar emerge as the main centres of LNG exports, accounting for around 40% of all LNG exports by 2040.
- ▶ Asia remains the dominant market for LNG imports, although the pattern of imports within Asia shifts, with China, India and Other Asia overtaking the more established markets of Japan and Korea, and accounting for around half of all LNG imports by 2040.
- ▶ Europe remains a key market, both as a 'balancing market' for LNG supplies and a key hub of gas-on-gas competition between LNG and pipeline gas (see pp 100-101).
- ▶ The precise profile of LNG volume growth will depend on the timing and availability of the new investments needed to finance the considerable expansion. The cyclical nature of LNG investments means there is a risk that the development of the LNG market will continue to be associated with periods of volatility.

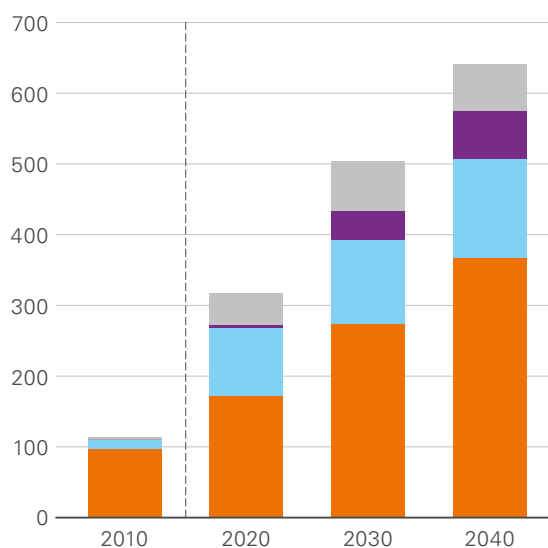
The increasing diversity of gas exports leads to greater competition between LNG and pipeline gas

Gas supply:
Europe

Bcm



Gas supply:
China

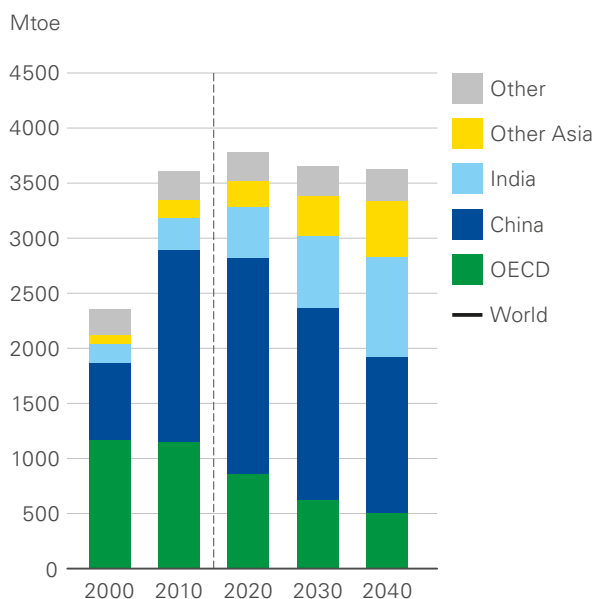


Key points

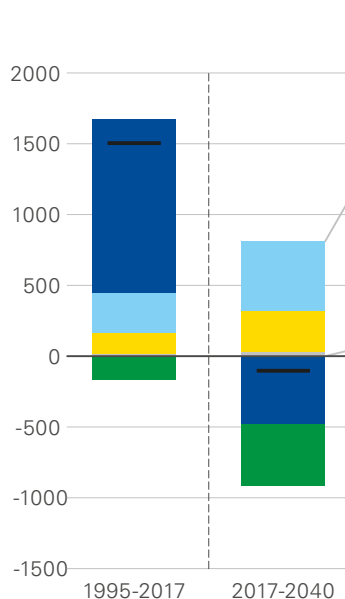
- ▶ The increase in LNG supplies leads to greater competition between LNG and pipeline gas, especially in Europe and China – two of the largest importers of gas.
- ▶ In the ET scenario, European gas production declines by 40%, causing Europe's import dependency to increase to around three-quarters in 2040.
- ▶ Europe's existing infrastructure means it has the capacity to increase substantially its imports of either LNG or pipeline gas, especially from Russia.
- ▶ The greater ease of transportation means pipeline gas has a marked cost advantage over LNG; the main constraint on pipeline imports is concerns about Europe's dependency on Russia for gas. In the ET scenario, the development of a globally integrated gas market eases these concerns, allowing Russia to increase slightly its share of European gas demand.
- ▶ In China, despite sizeable increases in domestic production, demand growth outstrips supply, causing import dependency to rise to over 40% by 2040. Around half of these additional imports are met by incremental pipeline capacity from Russia and other CIS countries, and the remainder from LNG.
- ▶ As in Europe, as well as pure cost considerations, China's choice of gas supply may also depend on the energy security implications of different sources of supply (some of these energy security issues are explored in the 'Less globalization' scenario on pp 72-75).

Global coal demand flat-lines, with falls in China and OECD offset by gains in India and other emerging Asian countries

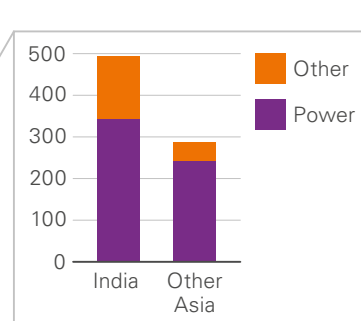
Coal demand by region



Change in coal demand by region



Increase in coal demand (2017-2040)

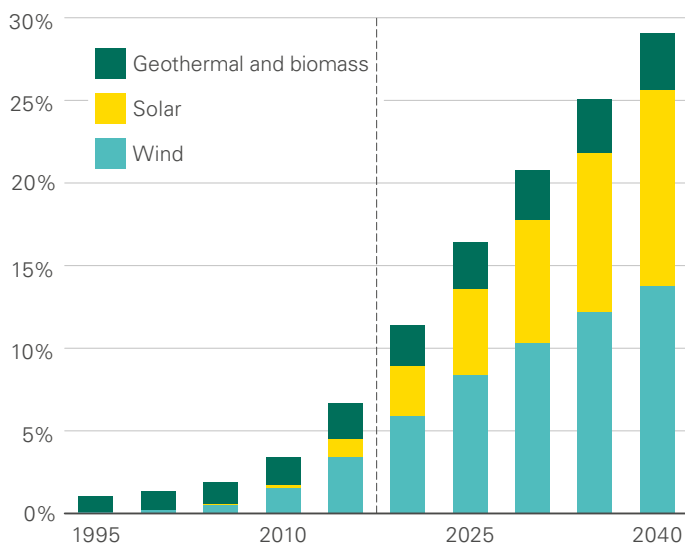


Key points

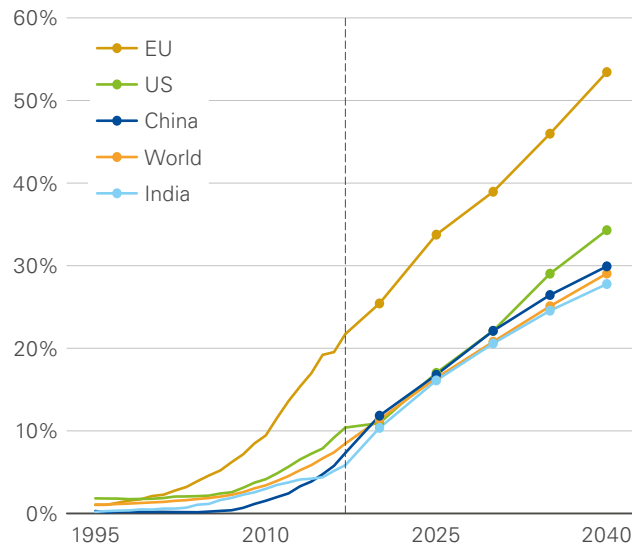
- ▶ Growth in coal consumption slows sharply relative to the past, although this masks contrasting patterns across countries and regions.
- ▶ In the ET scenario, global coal consumption broadly stagnates around current levels, in sharp contrast to the past 20 years or so when coal was the largest source of energy growth.
- ▶ The global market for coal continues to be dominated by China, where coal consumption falls for much of the Outlook as the economy adjusts to a more balanced, sustainable pattern of growth. The weakness in global coal consumption is compounded by significant falls in the OECD, as countries switch to cleaner, lower-carbon fuels.
- ▶ In contrast, coal demand within India and other emerging Asian economies increases. India is the largest growth market for coal, with its share of global coal consumption more than doubling to around a quarter in 2040.
- ▶ The majority of the increase in coal consumption in India and other developing Asian countries is used to meet robust growth in power demand as these economies grow and prosperity increases. The potential trade-off between the growth of power demand and the ability to decarbonize the power sector is discussed on pp 54-55.

Renewables are the largest source of energy growth, growing in importance in global power markets

Renewables share of power generation by source



Renewables share of power generation by region



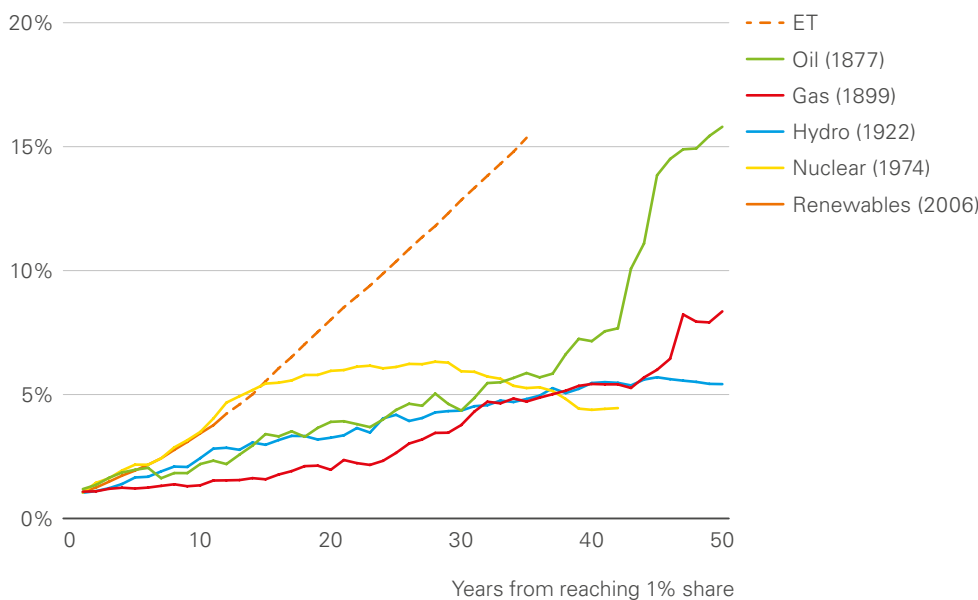
Key points

- ▶ Renewable energy grows strongly, with its share in global power markets increasing substantially.
- ▶ In the ET scenario, renewables in power are the fastest growing energy source (7.6% p.a.), accounting for around two-thirds of the increase in global power generation, and becoming the single largest source of global power generation by 2040. See pp 52-57 for a discussion of the outlook for global power markets.
- ▶ Both wind and solar power grow rapidly – increasing by a factor of 5 and 10 respectively – accounting for broadly similar increments to global power. This rapid growth is aided by continuing pronounced falls in the costs of wind and solar power as they move down their learning curves.
- ▶ The EU continues to lead the way in terms of the penetration of renewables, with the share of renewables in the EU power market increasing to over 50% by 2040. The challenge of managing the intermittency issues associated with this scale of renewables penetration increases towards the end of the Outlook.
- ▶ The growth in renewable energy is dominated by the developing world, with China, India and Other Asia accounting for almost half of the growth in global renewable power generation.

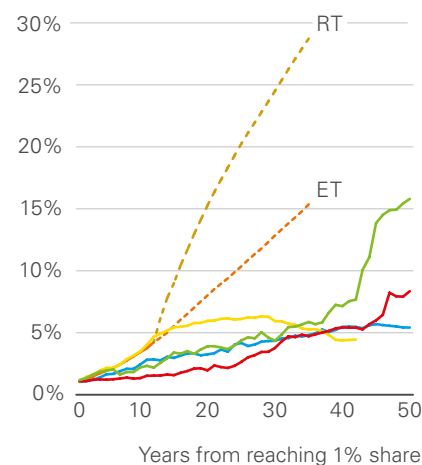
Renewables are set to penetrate the global energy system more quickly than any fuel in history

Speed of penetration of new fuels in global energy system

Share of world energy



Share of world energy



Key points

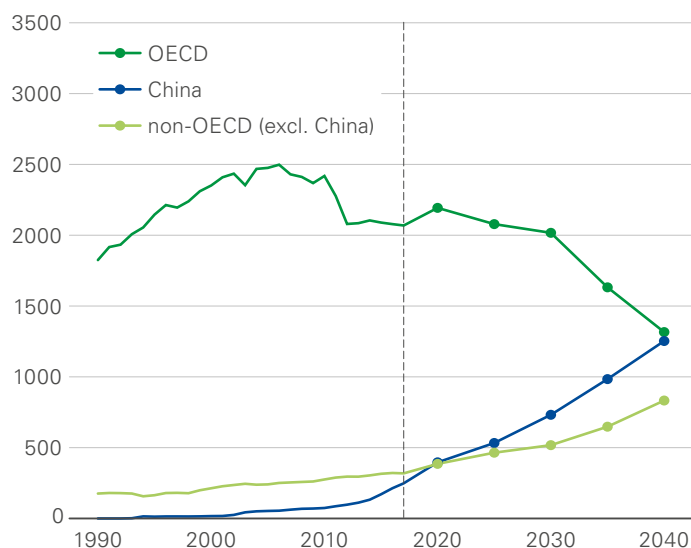
Renewables set to grow faster than any fuel in history

- ▶ Renewables are set to penetrate the global energy system more quickly than any fuel previously in history.
- ▶ Historically, it has taken many decades for new fuels to penetrate the energy system. For example, it took almost 45 years for the share of oil to increase from 1% of world energy to 10% in late 1800s/early 1900s. For natural gas, it took over 50 years from the beginning of the 20th century.
- ▶ This slow pace of change stems in large part from the capital intensity of the energy system. The global energy system is dominated by machines and buildings which are relatively long lived: cars tend to stay in the global car parc for over 10 years, power stations can operate for 30 years or more. These long lives act as a break on the pace at which new sources of energy can grow.
- ▶ In the ET scenario, the share of renewables in world energy increases from 1% to 10% in around 25 years. This is far quicker than any fuel has ever penetrated the energy system in history.
- ▶ In the Rapid transition scenario (pp 114-117), the growth of renewables is even quicker, with the share increasing from 1% to 10% in just 15 years. Such rapid growth would be literally off-the-charts relative to anything seen in history.

Nuclear and hydro power output continue to grow, although their shares within global power edge lower

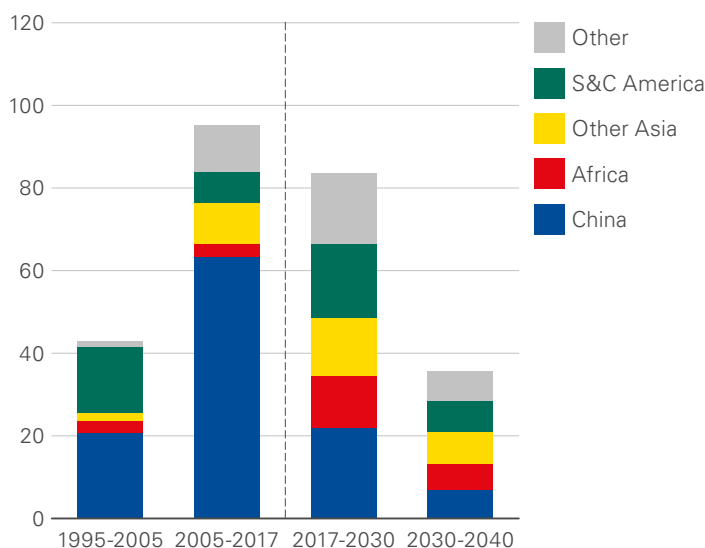
Nuclear

TWh



Hydro

TWh, annual average growth



Key points

- ▶ Nuclear and hydro power generation continue to grow over the Outlook, although less rapidly than overall power generation, such that their shares within overall power generation decline.
- ▶ Nuclear power in the ET scenario grows at an average rate of 1.1% p.a., broadly in line with the growth seen over the past 20 years or so.
- ▶ The continuing growth in nuclear power disguises two contrasting patterns. Nuclear energy within the OECD declines materially over the Outlook, as aging nuclear plants are decommissioned and there is limited investment in new capacity. In contrast, nuclear generation in China increases strongly, rising by 1000 TWh over the Outlook, with the level of nuclear generation in China by 2040 similar to that in the entire OECD.
- ▶ Hydro power increases by 1.3% p.a. over the Outlook. This is much slower than the growth seen over the past 20 years, as the previous rapid expansion in Chinese hydro power subsides. In the ET scenario, China remains the largest source of growth, but the increases in hydro power become more broadly based, with Other Asia, Latin America and Africa all recording material increases.

Carbon emissions

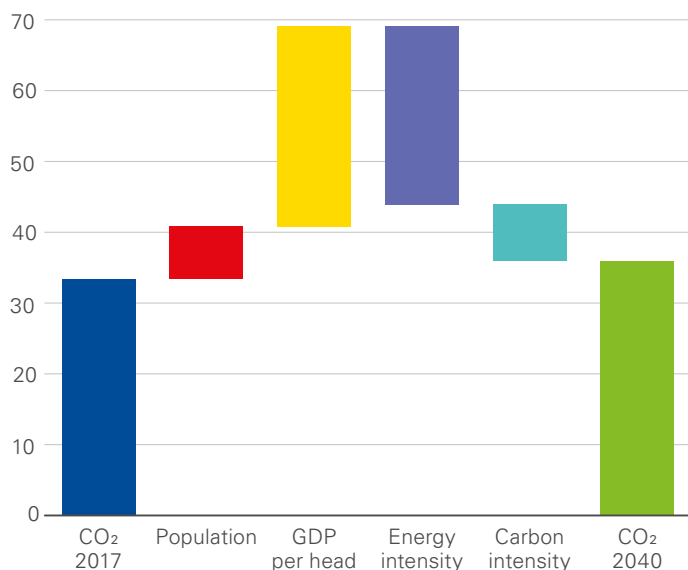
Summary

Alternative scenario: Rapid transition
Beyond 2040

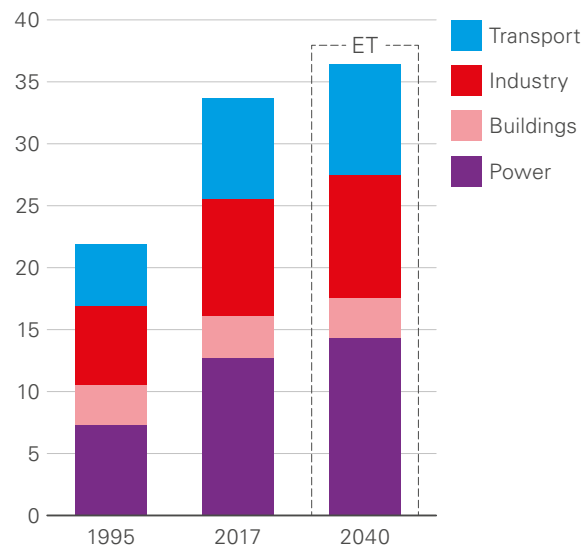
Carbon emissions increase further in the ET scenario with the power sector the main source of emissions

CO₂ emissions in ET scenario

Gt of CO₂



CO₂ emissions by sector

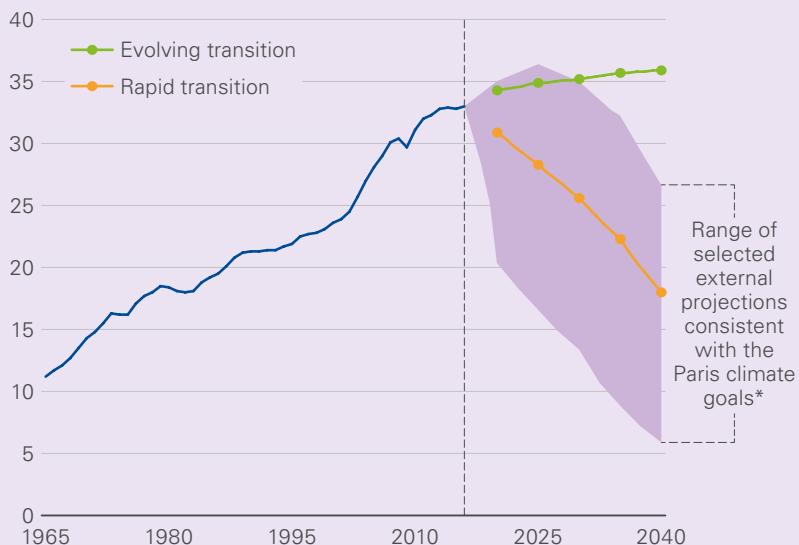


Key points

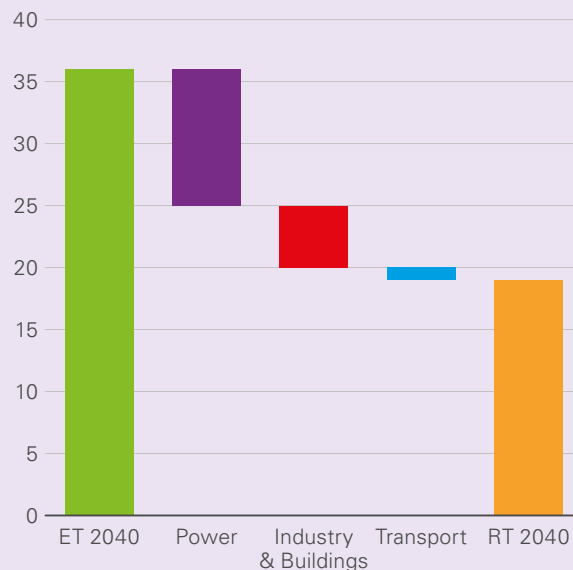
- ▶ In the ET scenario, CO₂ emissions from energy use continue to edge up through much of the Outlook, increasing by around 7% by 2040.
- ▶ The upward pressure on carbon emissions from continuing population growth and, most importantly, increasing prosperity in the developing world is largely offset by quickening gains in energy intensity and to a lesser extent by changes in the fuel mix reducing the level of carbon intensity.
- ▶ Although the rate of growth in carbon emissions is much slower than in the past 20 years, emissions are still growing more quickly than the sharp decline likely to be necessary to be consistent with achieving the Paris climate goals (see the alternative 'Rapid transition' scenario on pp 114-117).
- ▶ Despite the carbon intensity of the global power sector falling by around a third over the Outlook (see pp 60-61), the rapid growth in electricity consumption means that the power sector is the largest source of increase in CO₂ emissions over the same period, with its share in the global energy system increasing to around 40% by 2040. This is higher than industry or transport which each account for around a quarter of CO₂ from energy use, with buildings contributing the remainder (10%).

Alternative scenario: Rapid transition

Alternative scenario: a more rapid transition to a lower-carbon energy system

CO₂ emissionsGt of CO₂

*See page 139 for scenarios included

CO₂ in 2040: ET vs. RT scenario

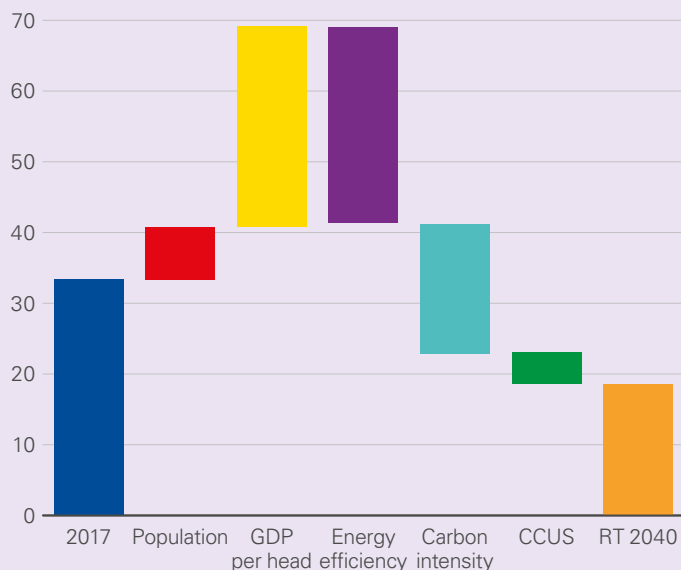
Key points

- ▶ The alternative 'Rapid transition' (RT) scenario combines all the policy measures in the lower-carbon scenarios for industry and buildings (pp 38-41); transport (pp 48-51) and the power sector (pp 58-61) in one single scenario.
- ▶ In the RT scenario, CO₂ emissions fall by around 45% by 2040 relative to current levels. The scale of this reduction is broadly in the middle of a range of external projections which claim to be consistent with meeting the Paris climate goals, and is broadly similar to the reduction in carbon emissions in the IEA's Sustainable Development Scenario.
- ▶ Around two-thirds of the reductions in CO₂ relative to the ET scenario stem from the substantial decarbonization of the power sector. The power sector is the single largest source of CO₂ emissions from energy use, and the extensive fuel-on-fuel competition means policy interventions can have significant impacts on the fuel mix.
- ▶ The reduction in CO₂ from industry and buildings accounts for much of the remaining reduction in emissions, reflecting improved efficiency, greater use of CCUS and switching into lower-carbon fuels.
- ▶ Despite the large number of policy measures and initiatives applied in the transport sector, the reduction in CO₂ is relatively small.

The power sector accounts for most of the CO₂ emissions savings

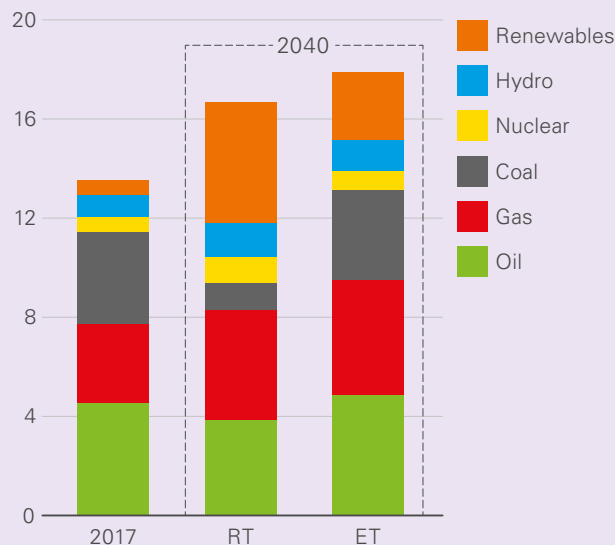
Alternative scenario: Rapid transition

The reduction in emissions in the Rapid transition scenario stems from greater efficiency, fuel switching and use of CCUS

CO₂ emissions in RT scenario, 2017-2040Gt of CO₂

Primary energy consumption by fuel

Billion toe



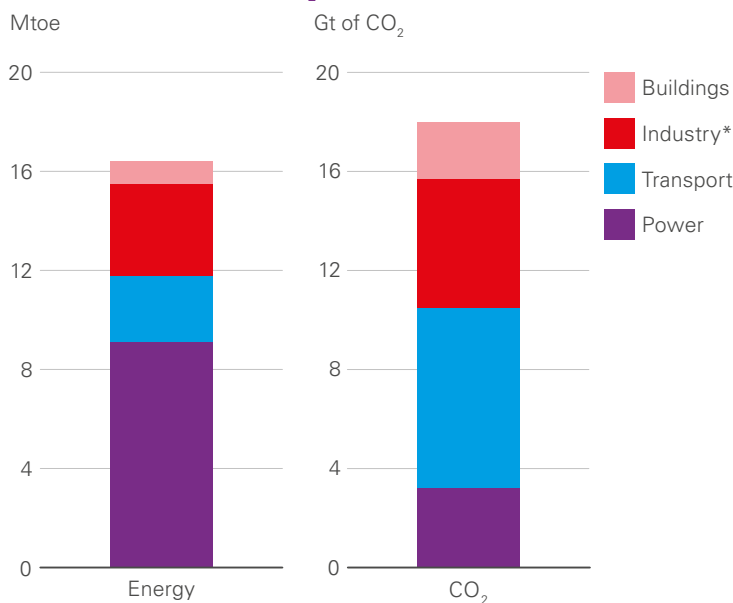
Key points

Oil and gas provide nearly half of global energy in 2040 in the RT scenario

- ▶ The fall in carbon emissions in the RT scenario relative to 2017 levels reflects a combination of: gains in energy efficiency; a switch to lower-carbon fuels; and greater use of CCUS.
- ▶ The gains in energy efficiency means energy demand increases by around 20% in the RT scenario by 2040, compared with a third in the ET scenario.
- ▶ The shift to lower-carbon fuels reflects a combination of rapid growth in renewable energy – which more than accounts for the entire increase in primary energy – and a sharp contraction in the use of coal. By 2040, renewables account for around 30% of primary energy.
- ▶ Despite the strong growth in renewables, oil and gas account for close to 50% of primary energy in 2040 in the RT scenario. The level of oil consumption falls to around 80 Mb/d in 2040, with roughly 60% of this remaining use in transport and much of the rest in the non-combusted sector. In contrast, gas continues to grow aided by growing use of CCUS – with close to a third of natural gas in the RT scenario in 2040 being used in conjunction with CCUS.
- ▶ CCUS is used in both power and industry and captures almost 4.5 Gt of CO₂ emissions by 2040 in the RT scenario.

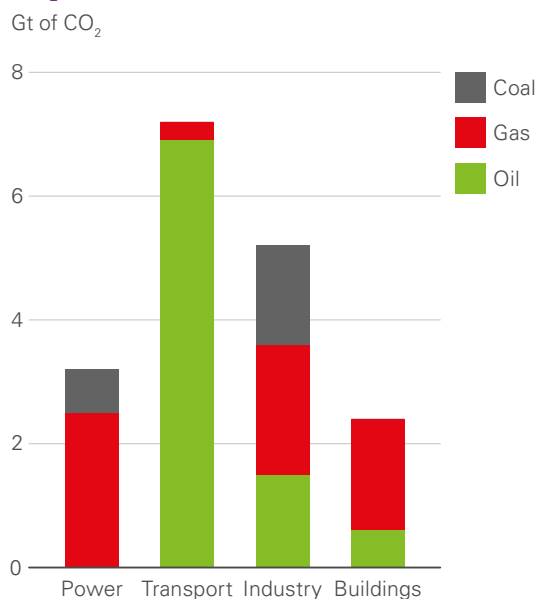
Beyond 2040: the challenge is to reduce hard-to-abate carbon emissions

RT scenario in 2040:
Energy demand and CO₂



*Industry includes non-combusted sector

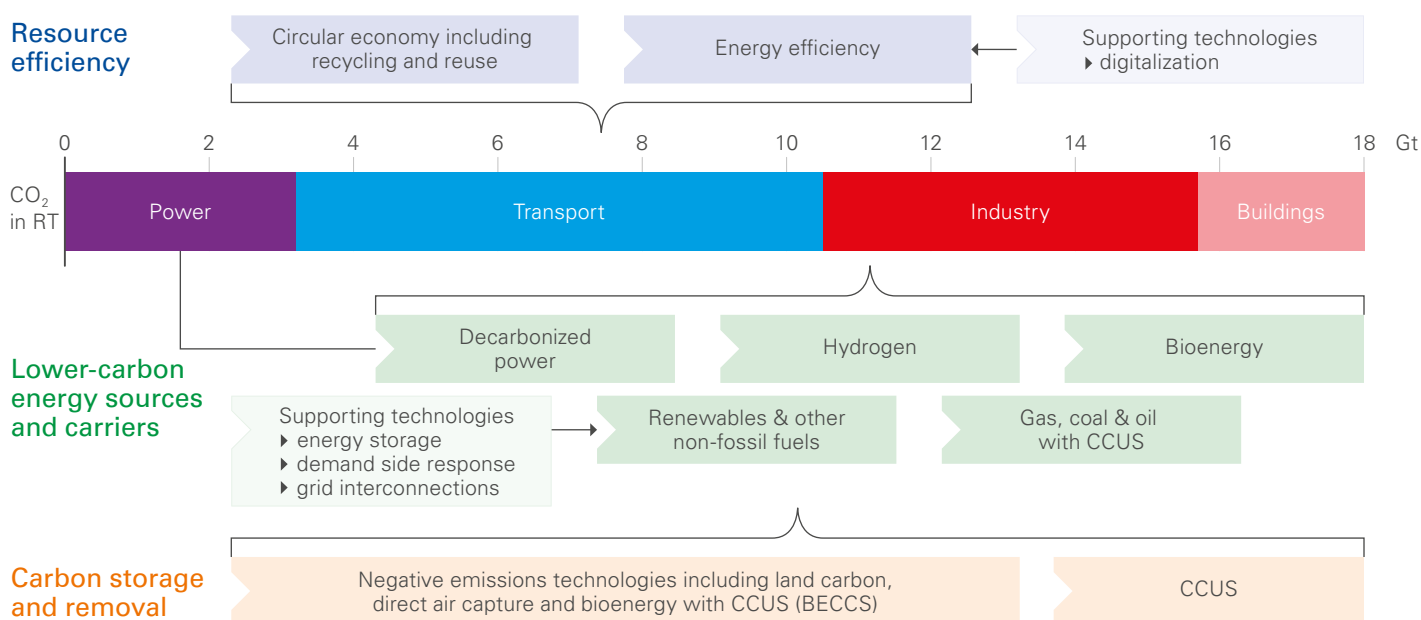
RT scenario in 2040:
CO₂ emissions by fuel and sector



Key points

- ▶ In the RT scenario, CO₂ emissions from energy use by 2040 fall by around 45% relative to current levels. Although such a reduction represents considerable progress, it implies that a significant level of CO₂ emissions (around 18 Gt) would still remain.
- ▶ Looking beyond 2040, in order to meet the Paris climate goals, these remaining emissions would need to be greatly reduced in the second half of the century and offset with negative emissions.
- ▶ These remaining emissions are concentrated in transport (7 Gt) and industry (5 Gt), with smaller contributions from power (3 Gt) and buildings (2 Gt).
- ▶ In transport, the majority of the emissions stem from the continuing use of oil (45 Mb/d) in 2040. More than half of this consumption stems from the use of oil in cars and light and medium-duty trucks which can be gradually electrified overtime. But the remainder is concentrated in modes of transport which are harder to electrify: including elements of heavy-duty trucks, aviation, and marine.
- ▶ In industry, much of the CO₂ emitted stems from the continuing use of coal (2 Gt) and gas (2 Gt) in activities that are hard and/or expensive to abate, either because they require high temperatures or where carbon is inherently involved in the production process, such as iron and steel, chemicals and cement.

A further substantial reduction in emissions is likely to require a wide range of improvements and changes



Key points

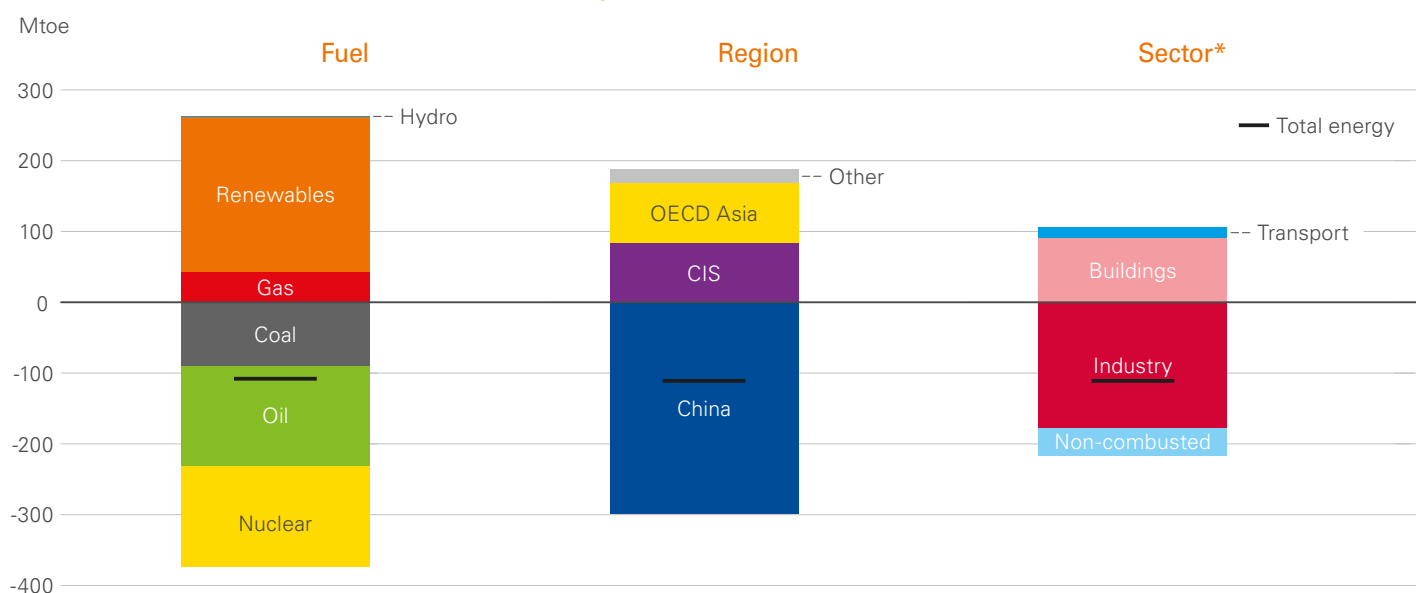
- ▶ A further substantial reduction in net CO₂ emissions from energy use beyond 2040 would likely require further improvements and changes across a number of fronts.
- ▶ A key development would be an (almost) complete decarbonization of the power sector, together with greater electrification of end-use activities. Decarbonization of the power sector would require more renewables – supported by improvements in energy storage and demand-side-response to ease the issues associated with intermittency – plus more CCUS in conjunction with natural gas and coal.
- ▶ But the IEA recently estimated that only around two-thirds of final energy use has the technical potential to be electrified, highlighting the need for other lower-carbon forms of energy (and energy carriers) for the remaining one-third. This includes hydrogen produced from decarbonized sources, bioenergy, and gas/coal/oil with CCUS.
- ▶ Two other over-arching developments are also likely to be important:
- ▶ Further gains in resource efficiency: including both increased use of circular economy techniques to mitigate demand for new materials and products, and accelerating gains in energy efficiency;
- ▶ Greater adoption of carbon removal techniques: including CCUS and negative emissions technologies, such as land carbon, direct air capture and BECCS.

Comparisons

Comparisons to previous BP Outlooks
Comparisons to external Outlooks

The largest revisions to the ET scenario relative to last year were to renewable energy and industrial demand in China

ET scenario in EO19 vs. EO18: difference in projected levels in 2040



Note: For comparison purposes, figures from the 2018 Energy Outlook (EO18) have been rebased to be consistent with the 2018 Statistical Review

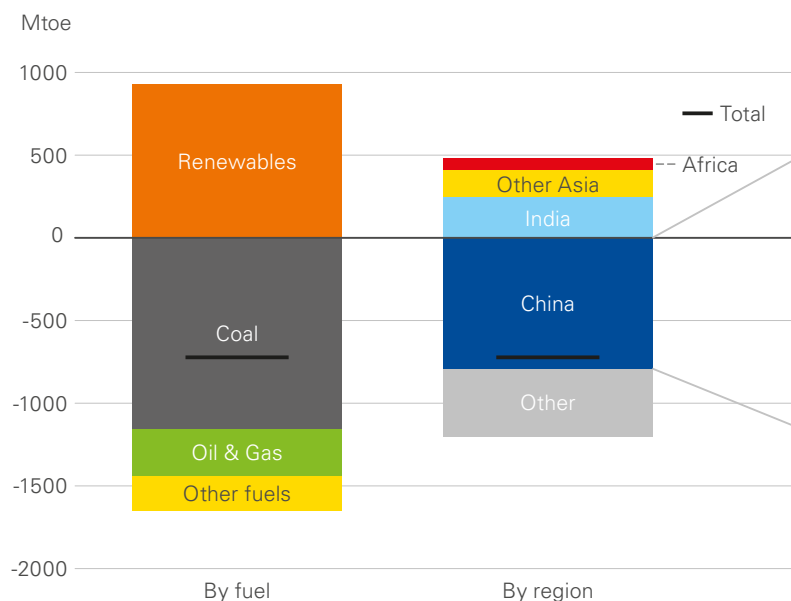
*Losses in the power sector have been allocated to end-use sectors

Key points

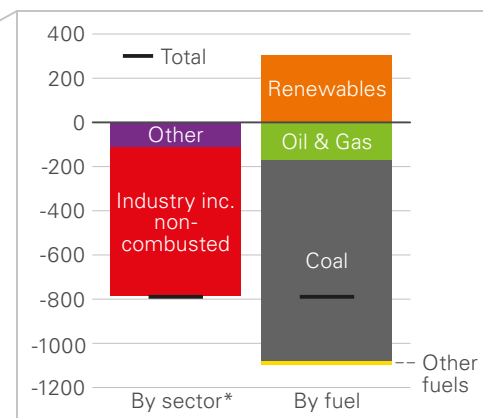
- ▶ Comparing the ET scenario with the same scenario in last year's *Energy Outlook*, overall energy demand has been revised down only very slightly, less than 1% in 2040, but this masks larger revisions across different fuels, regions and sectors.
- ▶ By fuel, the largest revision was an increase in renewable energy, up 9% (220 Mtoe) in 2040. This was offset by downward revisions to coal and nuclear – in part as renewables gained share relative to these fuels in the power sector – and to oil.
- ▶ By region, the largest revision was to Chinese energy consumption, which is 7% (300 Mtoe) lower than in last year's *Outlook*, reflecting the pace at which China is adjusting to a more sustainable pattern of economic growth.
- ▶ Much of the revision in China's energy demand is concentrated in industrial demand – which saw the biggest revision by sector – as China's economy transitions away from energy-intensive industrial activities and improves the efficiency of remaining industries.
- ▶ The revisions to the outlook for Chinese energy demand, and its implications for industrial demand and the growth of renewable energy, continue a series of revisions seen over the past five years – discussed on the next page.

The most significant surprise over the past 5 years has been the pace of adjustment in China

Revisions in 2035 energy versus 2014 Outlook: World



Revisions in 2035 energy versus 2014 Outlook: China



Note: for comparison purposes, figures from the 2014 *Energy Outlook* have been rebased to be consistent with the 2018 *Statistical Review*
 *Losses in the power sector have been allocated to end-use sectors

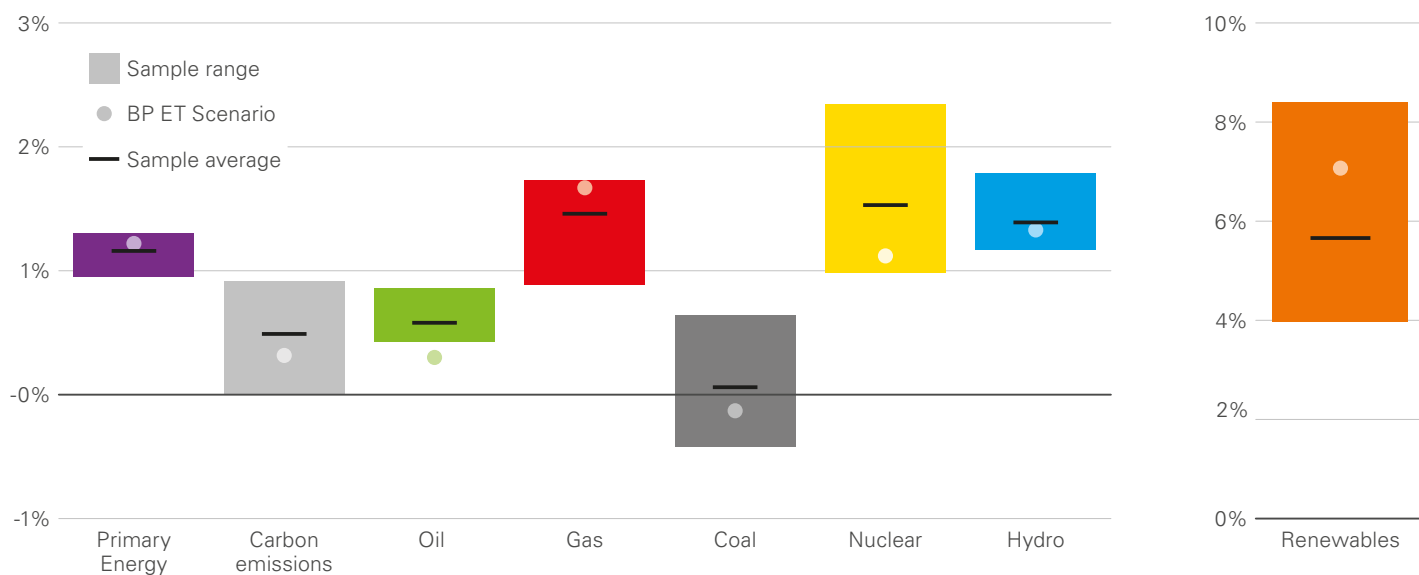
Key points

- ▶ Comparing the ET scenario with the base case in the 2014 *Energy Outlook* helps to highlight some of the major developments and surprises over the past 5 years.
- ▶ The most important factor driving revisions over the past 5 years has been the faster-than-anticipated pace of economic adjustment in China: rebalancing its economy away from energy-intensive industrial sectors and shifting to a cleaner, lower-carbon energy mix. These changes are most marked in the revisions to Chinese industrial and coal demand (-22% and -37% respectively in 2035).
- ▶ The softer prospects for Chinese energy demand has led to a downgrading in overall energy demand (-4%), partially offset by upward revisions to other parts of developing Asia and Africa as some Chinese industrial production is relocated to lower-income countries.
- ▶ The shift in China's fuel mix directly accounts for roughly 80% of the downward revision to global coal consumption, and around a third of the upward revision to the outlook for renewables over the past 5 years. The overall impact on renewables is even greater since the quicker adoption of renewable energy in China helps to drive down the costs of wind and solar energy as they move down their learning curves more quickly, increasing the penetration of renewables in other parts of the world.

Comparing the ET scenario with a sample of other Outlooks helps highlight areas of uncertainty

Energy consumption growth by fuel and carbon emissions, 2017-2040

% per annum



Note: see Annex for details of which external scenarios were included in the sample range

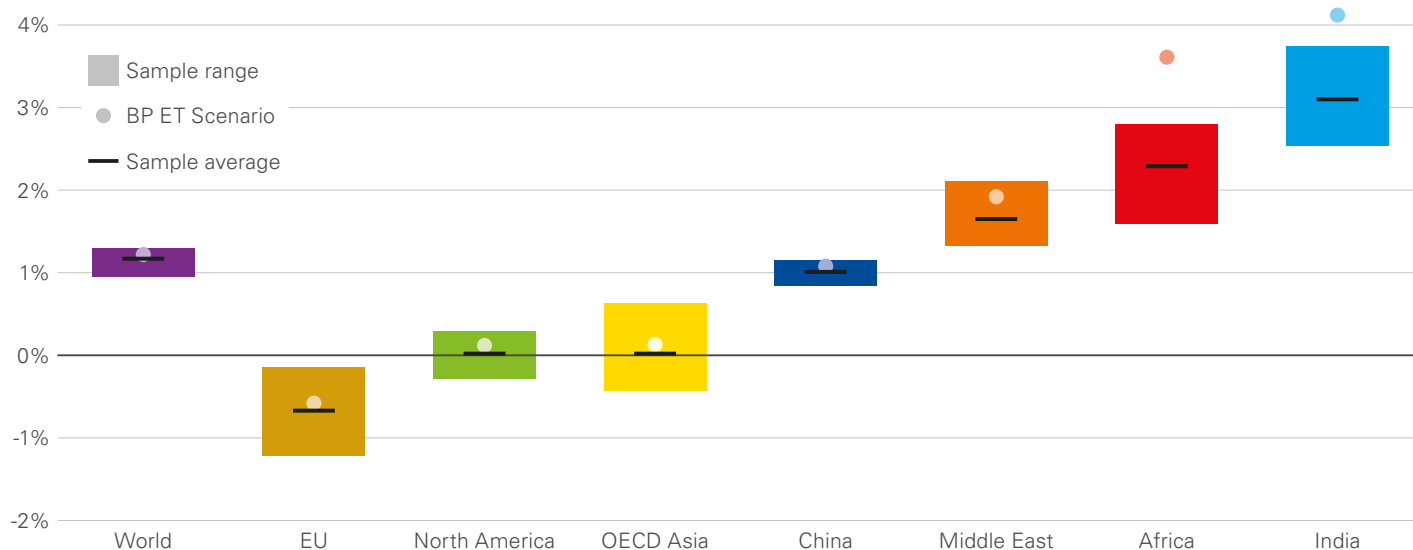
Key points

- ▶ Comparing the *Energy Outlook* with long-run energy projections published by other organizations helps to highlight differences of view and areas of uncertainty. To aid comparison, the ET scenario is compared with external scenarios whose assumptions for policy, technology and social preferences are most similar.
- ▶ There is a relatively narrow range of views about the growth of overall energy – varying between 0.9% and 1.3% p.a.. The ET scenario (1.2% p.a.) is just a touch above the sample average.
- ▶ The growth of oil demand in the ET scenario (0.3% p.a.) is lower than any of the external forecasts, perhaps reflecting the extent of vehicle efficiency gains in the ET scenario. In contrast, the ET scenario points to slightly stronger growth of natural gas than the sample average.
- ▶ The dispersion of views across the different projections – which is often an indicator of uncertainty – is greatest for renewables and nuclear energy. For renewables, this uncertainty stems from the difficulty of predicting future trends in policy support and technology. Much of the dispersion of views on nuclear may stem from different judgements about nuclear plant retirements. The ET scenario is towards the top of the range for prospects for renewables and towards the bottom for nuclear.

The ET scenario is close to sample average for developed markets, but projects faster growth in developing economies

Energy consumption growth by region, 2017-2040

% per annum



Note: see Annex for details of which external scenarios were included in the sample range

Key points

- ▶ Although the range of views about the overall growth in primary energy is relatively narrow, there is greater dispersion concerning the prospects for individual countries and regions.
- ▶ The ET scenario is relatively close to the sample average for energy demand growth in developed markets, such as North America, the EU and OECD Asia.
- ▶ In contrast, for some fast developing regions, such as Africa and India, the ET scenario is materially above the range of other projections. This may partly stem from the assumption in the ET scenario that as China shifts towards a more services-based economy, much of the growth in industrial production over the Outlook will be located in lower-income countries and regions, including India, Other Asia and Africa (see pp 30-31).
- ▶ A striking feature of the external projections is the extremely narrow range of views concerning the growth of Chinese energy demand, which varies from just 0.8-1.1% p.a.. This uniformity of views is particularly surprising given the changing energy needs of China as it adjusts to a more sustainable pattern of growth. This adjustment process has led to a series of downward revisions in the Outlook for Chinese energy demand in recent years (pp 126-127).

Annex

Key figures, definitions and sources

Key figures: Evolving transition scenario

Macro				Change (absolute)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
GDP (trillion US\$ PPP)	52	114	236	62	122	120%	107%	3.7%	3.2%
Population (billions)	5.7	7.5	9.2	1.8	1.7	31%	22%	1.2%	0.9%
GDP per capita (thousand US\$)	9	15	26	6	11	68%	69%	2.4%	2.3%
Energy intensity (toe per US\$m)	166	119	76	-47	-43	-28%	-36%	-1.5%	-1.9%
Net CO ₂ emissions (Gt of CO ₂)	21.9	33.4	36.0	11.5	2.5	53%	7%	1.9%	0.3%

	Consumption (Mtoe)			Shares (%)			Change (Mtoe)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995	2017	2040	1995- 2017	2017- 2040	1995- 2017	2017- 2040	1995- 2017	2017- 2040
Primary energy	8565	13511	17866				4946	4355	58%	32%	2.1%	1.2%
By fuel:												
Oil	3391	4538	4860	40%	34%	27%	1146	323	34%	7%	1.3%	0.3%
Gas	1816	3156	4617	21%	23%	26%	1340	1461	74%	46%	2.5%	1.7%
Coal	2224	3731	3625	26%	28%	20%	1507	-106	68%	-3%	2.4%	-0.1%
Nuclear	526	596	770	6%	4%	4%	71	173	13%	29%	0.6%	1.1%
Hydro	563	919	1245	7%	7%	7%	355	327	63%	36%	2.2%	1.3%
Renewables [†]	45	571	2748	1%	4%	15%	526	2177	1174%	381%	12.3%	7.1%
End-use sector*:												
Transport	1700	2817	3521	20%	21%	20%	1117	704	66%	25%	2.3%	1.0%
Industry	3760	5853	7443	44%	43%	42%	2093	1590	56%	27%	2.0%	1.1%
Non-combusted	510	856	1263	6%	6%	7%	346	407	68%	48%	2.4%	1.7%
Buildings	2595	3985	5638	30%	29%	32%	1390	1653	54%	41%	2.0%	1.5%
of which:												
Inputs to power	3236	5751	8972	38%	43%	50%	2515	3221	78%	56%	2.6%	2.0%

*Primary energy used in power is allocated according to final sector electricity consumption

†Renewables includes wind, solar, geothermal, biomass, and biofuels

	Consumption (Mtoe)			Shares (%)			Change (Mtoe)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
By region:												
OECD	5214	5738	5719	61%	42%	32%	524	-19	10%	0%	0.4%	0.0%
US	2070	2235	2223	24%	17%	12%	164	-12	8%	-1%	0.3%	0.0%
EU	1678	1689	1475	20%	13%	8%	12	-215	1%	-13%	0.0%	-0.6%
Other	1466	1814	2022	17%	13%	11%	348	208	24%	11%	1.0%	0.5%
Non-OECD	3351	7773	12147	39%	58%	68%	4422	4374	132%	56%	3.9%	2.0%
China	891	3132	4017	10%	23%	22%	2241	885	252%	28%	5.9%	1.1%
India	252	754	1928	3%	6%	11%	501	1174	199%	156%	5.1%	4.2%
Other Asia	395	944	1681	5%	7%	9%	549	737	139%	78%	4.0%	2.5%
Middle East	352	897	1391	4%	7%	8%	545	494	155%	55%	4.3%	1.9%
Russia	656	698	750	8%	5%	4%	43	52	7%	7%	0.3%	0.3%
Brazil	157	294	485	2%	2%	3%	137	191	87%	65%	2.9%	2.2%
Other	648	1054	1894	8%	8%	11%	406	841	63%	80%	2.2%	2.6%

	Supply			Change (absolute)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
Liquids production (Mb/d)	70	98	108	28	10	40%	10%	1.5%	0.4%
Oil	68	93	100	25	7	36%	8%	1.4%	0.3%
Biofuels	0	2	4	2	2	669%	69%	9.7%	2.3%
Other liquids*	2	3	4	1	1	74%	34%	2.5%	1.3%
Gas production (Bcm)	2094	3680	5370	1587	1690	76%	46%	2.6%	1.7%

*Includes GTLs/CTLs and refinery gains

Key figures: Rapid transition scenario

Macro				Change (absolute)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
Energy intensity (toe per US\$m)	166	119	70	-47	-49	-28%	-41%	-1.5%	-2.3%
Net CO ₂ emissions (Gt of CO ₂)	21.9	33.4	18.0	11.5	-15.4	53%	-46%	1.9%	-2.7%

	Consumption (Mtoe)			Shares (%)			Change (Mtoe)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040
Primary energy	8565	13511	16390				4946	2879	58%	21%	2.1%	0.8%

By fuel:

Oil	3391	4538	3845	40%	34%	23%	1146	-693	34%	-15%	1.3%	-0.7%
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Coal	2224	3731	1079	26%	28%	7%	1507	-2653	68%	-71%	2.4%	-5.3%
Nuclear	526	596	1012	6%	4%	6%	71	416	13%	70%	0.6%	2.3%
Hydro	563	919	1403	7%	7%	9%	355	484	63%	53%	2.2%	1.9%
Renewables [†]	45	571	4708	1%	4%	29%	526	4138	1174%	725%	12.3%	9.6%

End-use sector*:

Transport	1700	2817	3294	20%	21%	20%	1117	477	66%	17%	2.3%	0.7%
Industry	3760	5853	6429	44%	43%	39%	2093	575	56%	10%	2.0%	0.4%
Non-combusted	510	856	1263	6%	6%	8%	346	407	68%	48%	2.4%	1.7%
Buildings	2595	3985	5405	30%	29%	33%	1390	1419	54%	36%	2.0%	1.3%

of which:

Inputs to power	3236	5751	9109	38%	43%	56%	2515	3358	78%	58%	2.6%	2.0%
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*Primary energy used in power is allocated according to final sector electricity consumption

†Renewables includes wind, solar, geothermal, biomass, and biofuels

	Consumption (Mtoe)			Shares (%)			Change (Mtoe)		Change (%)		Change (% per annum)	
	1995	2017	2040	1995	2017	2040	1995-2017	2017-2040	1995-2017	2017-2040	1995-2017	2017-2040

By region:

OECD	5214	5738	5316	61%	42%	32%	524	-422	10%	-7%	0.4%	-0.3%
US	2070	2235	2075	24%	17%	13%	164	-159	8%	-7%	0.3%	-0.3%
EU	1678	1689	1302	20%	13%	8%	12	-387	1%	-23%	0.0%	-1.1%
Other	1466	1814	1939	17%	13%	12%	348	125	24%	7%	1.0%	0.3%
Non-OECD	3351	7773	11074	39%	58%	68%	4422	3301	132%	42%	3.9%	1.6%
China	891	3132	3700	10%	23%	23%	2241	568	252%	18%	5.9%	0.7%
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Other Asia	395	944	1515	5%	7%	9%	549	571	139%	61%	4.0%	2.1%
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Russia	656	698	713	8%	5%	4%	43	15	7%	2%	0.3%	0.1%
Brazil	157	294	437	2%	2%	3%	137	142	87%	48%	2.9%	1.7%
Other	648	1054	1777	8%	8%	11%	406	724	63%	69%	2.2%	2.3%

Definitions

Data

- ▶ Unless noted otherwise, data definitions are based on the BP Statistical Review of World Energy
- ▶ Primary energy comprises commercially-traded fuels, and excludes traditional biomass
- ▶ The primary energy values of nuclear, hydro and electricity from renewable sources have been derived by calculating the equivalent amount of fossil fuel required to generate the same volume of electricity in a thermal power station assuming a conversion efficiency of 38% (a global average for thermal power generation)
- ▶ Gross Domestic Product (GDP) is expressed in terms of real Purchasing Power Parity (PPP) at 2010 prices

Sectors

- ▶ Transport includes energy used in road, marine, rail and aviation
- ▶ Industry includes energy combusted in manufacturing; construction; the energy industry including pipeline transport; and for transformation processes outside of power generation
- ▶ Non-combusted includes fuel that is used as a feedstock to create materials such as petrochemicals, lubricant and bitumen
- ▶ Buildings includes energy used in residential and commercial building, plus agriculture, fishing and IEA's non-specified sector "Other"
- ▶ Power includes inputs into power generation (including combined heat and power plants)

Regions

- ▶ OECD is approximated as North America plus Europe plus OECD Asia
- ▶ China refers to the Chinese Mainland
- ▶ Other Asia includes all countries and regions in non-OECD Asia excluding mainland China and India

Fuels, carbon and materials

- ▶ Oil unless noted otherwise includes: crude; natural gas liquids (NGLs); gas-to-liquids (GTLs); coal-to-liquids (CTLs); condensates; and refinery gains
- ▶ Liquids includes all of oil plus biofuels
- ▶ Renewables unless otherwise noted includes wind, solar, geothermal, biomass, and biofuels and excludes large-scale hydro
- ▶ Non-fossils includes renewables, nuclear and hydro
- ▶ References to carbon emissions consider only CO₂ emissions from fuel combustion
- ▶ Plastics includes synthetic fibres
- ▶ Single-use plastics refers to plastic packaging and other single uses, such as plastic straws and cups

Comparison and other key data sources

Comparison data sources used to compare with Evolving transition scenario:

IEA: New Policies Scenario, International Energy Agency, *World Energy Outlook 2018*, Paris, France, Nov. 2018
 IEEJ: Institute of Energy Economics Japan, *Outlook 2019-Energy transition and a thorny path for 3E challenges*, Tokyo, Japan, Oct. 2018
 IHS: IHS Markit, *Rivalry: the IHS Markit view of the energy future (2018-2050)*, Jul. 2018
 OPEC: Organization of the Petroleum Exporting Countries, *World Oil Outlook 2040*, Sep. 2018
 Equinor: *Energy Perspectives 2018 – Long-term macro and market outlook*, May 2018
 ExxonMobil: *2018 Outlook for Energy: A View to 2040*, Feb. 2018
 CNPC: CNPC Economics & Technology Research Institute, *Energy Outlook 2050*, 2018
 EIA: US Energy Information Administration, *International Energy Outlook 2017*, Washington, D.C., United States, Sep. 2017

Comparison data sources used to compare with Rapid transition scenario:

Shell: Sky Scenario, Feb. 2018
 IEA: Sustainable Development Scenario, *International Energy Agency, World Energy Outlook 2018*, Paris, France, Nov. 2018
 IPCC: P1 Illustrative Model Pathway, *Global Warming of 1.5 C, Intergovernmental Panel on Climate Change*, Oct. 2018
 Equinor: Renewal Scenario, *Energy Perspectives 2018*, May 2018

Other key data sources:

BP p.l.c., *BP Statistical Review of World Energy*, London, United Kingdom, Jun. 2018
 International Energy Agency, *Energy Balances of Non-OECD Countries*, Paris, France, 2018
 International Energy Agency, *Energy Balances of OECD Countries*, Paris, France, 2018
 UN Population Division, *World Population Prospects: The 2017 Revision*, New York, United States, 2017

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Acknowledgements

Data compilation: Centre for
Energy Economics Research and
Policy, Heriot-Watt University
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